Selected physico-chemical properties of extrudates from white yam (*Dioscorea rotundata*) and bambara nut (*Vigna subterranean*) blends

O.B. Oluwole [1], A.A. Olapade[2*], S.O. Awonorin[3] and F.O. Henshaw[3]

[1]Federal Institute of Industrial Research, Oshodi, Lagos, Nigeria
[2]Department of Food Technology, University of Ibadan, Ibadan, Oyo State Nigeria
[3]Department of Food Science and Technology, University of Agriculture, Abeokuta, Ogun State, Nigeria

* Corresponding author's e-mail: aaolapade@yahoo.com, aa.olapade@mail.ui.edu.ng

Abstract. This study was conducted to investigate effects of extrusion conditions on physic-chemical properties of blend of yam and bambara nut flours. Blend of white yam grit (750 µm) and Bambara nut flour (500 µm) in ratio 4:1 respectively was extrusion cooked at varying screw speeds 50-70rpm, feed moisture 12.5-17.5% (dry basis) and barrel temperatures 130-150 °C. Extrusion variables employed included barrel temperature (BT), screw speed (SS) and feed moisture content (FM), while physico-chemical properties of extrudates investigated were expansion ratio (ER), bulk density (BD) and trypsin inhibition activity (TIA). The results revealed that all the extrusion variables had significant effects ($p<0.05$) on the product properties considered in this study. Expansion ratio values ranged 1.55-2.06; bulk density values ranged 0.76-0.94 g/cm^3, while trypsin inhibition activities were 1.01-8.08 mg/100g sample.

Keywords: Yam-bambara blend, extrusion cooking, physico-chemical properties

INTRODUCTION

Extrusion cooking has been used as an important technique for modification and manufacture of a wide variety of traditional and novel foods and food blends (Nwabueze *et al*., 2007; Sobota and Rzedzicki, 2009; Jisha *et al*., 2010; Oluwole and Olapade, 2011). Expanded snack foods, ready-to-eat cereals and dry pet foods are manufactured from cereals and starches by high temperature short time extrusion cooking (Njoki and Faller, 2001; Marcos *et al*., 2008). The elevated pressure and high temperature applied during the process result in altered physical and chemical properties of the extruded products thereby modifying the functional properties of food blend (Iwe *and Ngoody*, 2000). Nutritional effects of processing however depend on factors including type of extruder, process parameters and screw configuration (Iwe *and Ngoddy*, 2000).

White Yam (*Dioscorea rotundata*) is a good source of carbohydrates, vitamins and minerals, as well as some essential amino acids (Ugwu, 2009). Yam is traditionally eaten in Nigeria as fried yam slices, cooked or boiled or even eaten in roasted forms. It is also processed into flour and cooked as a stiff porridge called 'amala' or processed into instant pounded yam flour usually consumed in the some parts of Nigeria. Bambara nut (*Vigna subterranean*) is an indigenous African grain legume and is one of the more important crops grown on the African continent (Abu-Salem and Abou-Arab, 2011). It contains about 24% protein with a good balance of the essential amino acids and relatively high proportions of lysine (6-8%) and methionine (1-3%). The major component of the bean is carbohydrate mainly starch, which is up to 50%. The minor components in this bean include minerals, vitamins and antinutritional factors such as trypsin inhibitors and polyphenols (Eltayeb *et al*. 2011).

In developing countries such as Nigeria starch based foods are the major staples and have resulted in protein energy malnutrition of adults and infants. However the utilization of locally grown crops for the production of nutritious convenient recipes in lesser developed countries (LDCS) has been seriously stressed by international agencies as a most suitable channel for addressing the deepening world food problem (Wolfe, 1992). Consequently the development of extruded food products using a combination of white yam and white Bambara nut could serve as a means of alleviating hunger among the populace particularly in the lesser developed countries.

Several authors have reported on extrusion cooking of root and tuber crops (Suknark *et al*., 1999; Iwe *and Ngoddy*, 2000; Budi and Jenshinn, 2009). There is however dearth of information on extrusion cooking of white yam or white yam in combination with bambara nut. It was the objective of this study therefore to determine the effect of some selected process variables of screw speed, barrel temperature and feed moisture of extrusion cooking on some desirable quality attributes in the extruded yam-bambara blends.

MATERIALS AND METHODS

White yam and cream coloured bambara nut were the major raw materials employed in this study. White yam tubers were obtained from National Root Crop Research Institute (NRCRI), Umudike, Abia State, Nigeria, while bambara nut was obtained from Mile 12 market in Lagos, Nigeria. The yam tubers (*Dioscorea rotundata*) used in this study were subjected to some preliminary operations such as peeling, washing, slicing (5mm thick), parboiling at 70 °C for 20 min and drying at 60 °C in a tray drier (model 1999, Germany) for 8 h. The dried yam slices were milled into grits (750 µm) using a Hammer mill (FIIRO model 1997, Nigeria). Bambara nut was soaked in excess water at room temperature (30±2 °C) for 8 h followed by manual dehulling, then drying at 60 °C for 8 h and milling into flour (500 µm) using the hammer mill. The samples were sealed in low density polyethylene bags and stored at 4 °C for subsequent use.

Yam grits and bambara flour at ratio 4:1 (w/w) was prepared and thoroughly blended together. Moisture content of the samples was determined using an oven drying method (AOAC, 1995). A Box behnken experimental design was employed to determine the effect of selected extrusion variables of barrel temperature (BT), screw speed (SS) and feed moisture content (FM) on the extrudate parameters of expansion ratio (ER), bulk density (BD)and trypsin inhibition activity (TIA). Extrusion variables were all tested at three levels (-1 to +1). The moisture content of the blend was adjusted to the desired feed moisture content by addition of calculated amount of distilled water using the equation (1) of Oluwole and Olapade (2011).

$$Q = A(Mf - Mi)/(1 + Mi) \quad ------- \quad Eq\,1$$

Where A = initial mass of the sample (kg)
Mi = initial fraction of moisture content of the blend (db)
Mf = desired fraction of moisture content of the blend (db)
Q = mass of water to be added to the sample (kg)

The mixtures were packaged and allowed to equilibrate inside low density polyethylene bags for 4 h before extrusion cooking. A single screw extruder (Komet, 1993 model, Germany) with length to diameter ratio of 3:1 and die opening of 8 mm was used in this study. Extrusion cooking of the mixtures was carried out as shown in transformed matrix (Table 1). For each run, the extruder temperature was stabilized using 8 kg soybean grits. At the steady state for each run sample was collected inside open stainless steel pan, allowed to cool then packaged inside low density polyethylene bags and stored under refrigeration (4 °C).

Expansion ratio was determined by measuring the diameter of extrudates using Venier caliper (Multitoyo, Japan) . Expansion ratio was expressed as ratio of the extrudate diameter to the diameter of the extruder's die opening. Bulk density was expressed as the mass/volume ratio of extrudates ground to pass through a 250 µm sieve. One hundred gram of the sample was weighed into a 250 ml measuring cylinder. Both the cylinder and the content were gently tapped 10 times against palm of hand and the volume occupied by the content was noted. The loose density was determined without tapping the measuring cylinder. Each treatment was done in triplicate. Trypsin inhibition activity was determined in the Bambara nut, white yam and extrudates using the established procedure of previous workers (Kakade *et al*., 1974).

RESULTS AND DISCUSSION

There results of extrudates' parameters investigated in this study are presented in Table 1. Expansion ratio values for extrudates of yam-bambara varied from 1.50 to 2.06 with the mean value of 1.85±0.06. The mathematical model for estimating ER is presented in Equation 2. The value of R^2 for the model was 0.95, which is an indicative that the model will predict the values of ER provided the values of variables were within the studied range in this study.

$$ER = 2.05 - 0.06BT + 0.019SS + 0.044\mathrm{FM} - 0.088\mathrm{BT} * \mathrm{SS} - 0.073\mathrm{BT} * \mathrm{FM} + 0.09\mathrm{SS} * \mathrm{FM} - 0.24\mathrm{BT2} + 0.036\mathrm{SS2} - 0.21\mathrm{FM2} ------ (2) \quad (R^2=0.95)$$

The significant model terms are barrel temperature, interaction between barrel temperature and screw speed, screw speed and feed moisture and quadratic effect of barrel temperature and feed moisture content. These significances are revealed in Figures 1 and 2. Figure 1 shows that ER increased with increase in Screw speed, while it also increased with increase in barrel temperature up to a point when it started decreased as a result of quadratic effect of barrel temperature on expansion ratio. Figure 2 presents effect of combination of feed moisture content and screw speed on ER of extrudates of yam-bambara blend. It was observed in this case that ER increased with increase in SS. Also the quadratic effect of FM on ER was conspicuously revealed in the response surface plot. Expansion ratio and bulk density of extruded food products have been reported as the most useful indices of quality in expanded food products (Thymi *et al*., 2005). High barrel temperatures have also been reported to favour high expansion ratio in extruded food products (Thymi *et al*., 2005).

It appears that at higher screw speeds, the feed blend were more properly homogenized and that favoured the production of extrudates of higher expansion ratio than at lower screw speeds of 50rpm and 60rpm. Similar observations have been reported in some extruded rice, corn products, sweet potato – soya mixtures (Iwe, 1998; Iwe and Ngoddy, 2000).

Bulk density values observed in this study were 0.74-0.94 g/cm^3 with mean value of 0.83±0.04 g/cm^3. The model for determination of value of BD is given in Eq. (3). The value of R^2 for the model was 0.95, which is an indicative that the model will predict the values of bulk density with higher degree of accuracy provided the values of variables were within the studied range in this study. The only significant term in the model is barrel temperature, which shows that bulk density of extrudate is only significantly affected by barrel temperature during extrusion cooking operation of yam-bambara blend.

$$BD = 0.82 - 0.05BT - 0.013SS - 0.022FM + 0.02BT * SS + 0.015BT * FM - 0.03SS * FM - 0.032BT2 + 0.033SS20.017FM2 - - - - - - - - (3) \quad (R^2=0.82)$$

Visual observations of effects of extrusion variables of BT, SS and FM on bulk density are presented in Figures 3 and 4. The extrusion variables of screw speed and feed moisture, though not significantly ($p>0.05$), were also found to have effects on the bulk density of the extrudates. Bulk density had been reported to be one of the most important indices of quality in extruded food products (Osundahunsi, 2006). The lower the bulk density of the extrudates, the higher the expansion ratio of the extrudates as they have been reported to be negatively correlated (Iwe, 1998; Iwe and Ngoddy, 2000; Nwabueze, 2008). High barrel temperatures of up to 140 °C have been found to reduce density of an expanded wheat snack (Thymi *et al.*, 2005), hence the lower density values of the extrudates at higher barrel temperatures.

The values of TIA varied considerably for extrudates of yam-bambara nut blend with a mean value of 5.97±1.0 mg/100g sample. Highest value of 8.08 mg/100g was obtained at 130 °C, 70 rpm and 15% for barrel temperature, screw speed and feed moisture content respectively. The least value 0f 1.62 mg/100g for TIA was observed at 150 °C barrel temperature, 60 rpm screw speed and 17.5% feed moisture content. Equation 4 expresses model for prediction of TIA with coefficient of prediction equaled 0.87. In this case both linear and quadratic effects of barrel temperature were significant terms of the model.

$$TIA = 6.40 - 2.03BT + 0.23SS - 0.26FM - 0.93BT * SS + 0.13BT * FM + 0.19SS * FM - 1.44BT2 + 1.1SS2 - 0.95FM2 - - - - - - - (4) \qquad (R^2=0.87)$$

Generally there was a reduction in the trypsin inhibitor content in the extrudates as the barrel temperature increased from 130 °C to 150 °C at all the screw speed i.e. 50 to 70 rpm (Figure 5). Also at all the feed moisture levels i.e. 12.5% to 17.5% employed in this study, there are drastic reduction of trypsin inhibition activity as the barrel temperature increased from 140 °C to 150 °C while keeping other extrusion condition constant (i.e. screw speed of 70 rpm) (Figure 6). Similar results were reported for trypsin inhibition activity of extruded soy-potato (Iwe and Ngoddy, 2000) and extruded acha/soybean (Anuonye *et al.*, 2007). It was reported that heat generally played a significant role in reducing trypsin inhibitor in any food product (Wanasundara and Ravindran, 1992). The observed results were in agreement with the observation of Anuonye *et al.* (2007) who reported for acha/soybean that extrusion cooking reduced TIA by about 70-97% with feed moisture and barrel temperature having the greatest influence. Nwabueze et al. (2007) also reported that extrusion cooking resulted in reduction in TIA of breadfruit based spaghetti type.

CONCLUSION

The study had been able to show that:

1. It is possible to prepared complementary food from blend of acha and cowpea flours
2. Expansion ratio values of extrudates ranged from 1.50 to 2.06 and it was significantly affected by extrusion variables of barrel temperature and interactions among the variables.

3. Bulk density values for the extrudates ranged from 0.74 to 0.94 g/cm^3 with mean value of 0.03 g/cm^3 and it increased with increase in barrel temperature.
4. Trypsin inhibition activity of the extrudates was significantly reduced by increase in barrel temperature used in this study.

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Table1: Matrix transformation of the experimental design runs and extrusion conditions

Experimental run	Variables code			Variables actual value			Response*		
	BT	SS	FM	BT (°C)	SS (rpm)	FM (%)	ER	BD (g/ml)	TIA (mg/100g)
1	0	1	1	140	70	17.5	2.06±0.12	0.78±0.02	6.77±0.23
2	-1	-1	0	130	50	15.0	1.79±0.13	0.91±0.04	6.77±0.54
3	0	0	0	140	60	15.0	2.00±0.11	0.82±0.03	6.39±0.43
4	0	0	0	140	60	15.0	2.01±0.14	0.81±0.03	6.30±0.65
5	0	0	0	140	60	15.0	2.00±0.13	0.80±0.04	6.25±0.40
6	0	0	0	140	60	15.0	2.02±0.11	0.82±0.03	6.35±0.32
7	+1	-1	0	150	50	15.0	1.90±0.13	0.76±0.05	5.87±0.43
8	+1	0	-1	150	60	12.5	1.50±0.10	0.74±0.10	1.01±0.23
9	-1	+1	0	130	70	15.0	1.95±0.07	0.84±0.07	8.08±0.25
10	+1	0	+1	150	60	17.5	1.50±0.06	0.78±0.05	1.67±0.43
11	0	-1	+1	140	50	17.5	1.85±0.16	0.86±0.06	4.90±0.33
12	0	+1	-1	140	70	12.5	1.81±0.06	0.94±0.07	7.82±0.76
13	+1	+1	0	150	70	15.0	1.73±0.16	0.77±0.05	3.46±0.49
14	0	-1	-1	140	50	12.5	1.91±0.07	0.90±0.06	6.70±0.52
15	-1	0	-1	130	60	12.5	1.55±0.15	0.86±0.04	6.60±0.55
16	-1	0	+1	130	60	17.5	1.84±0.07	0.84±0.03	6.79±0.71
17	0	0	0	140	60	15.0	2.03±0.11	0.82±0.04	6.31±0.87
Means							1.85±006	0.83±0.04	5.79±1.0

*Means of three replicates

BT=Barrel Temperature, SS=Screw speed, FM=Feed moisture content, ER=Expansion ratio, BD=Bulk density, EM= Extrudate moisture content, TIA= Trypsin inhibition activity

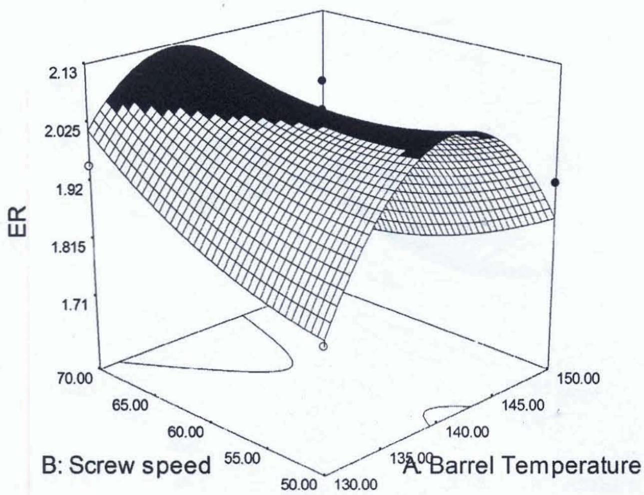

Figure 1: Response surface of ER as a function BT and SS

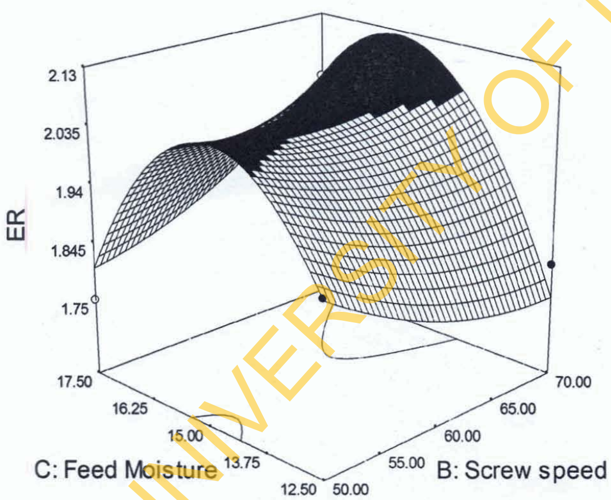

Figure 2: Response surface of ER as a function of FM and SS

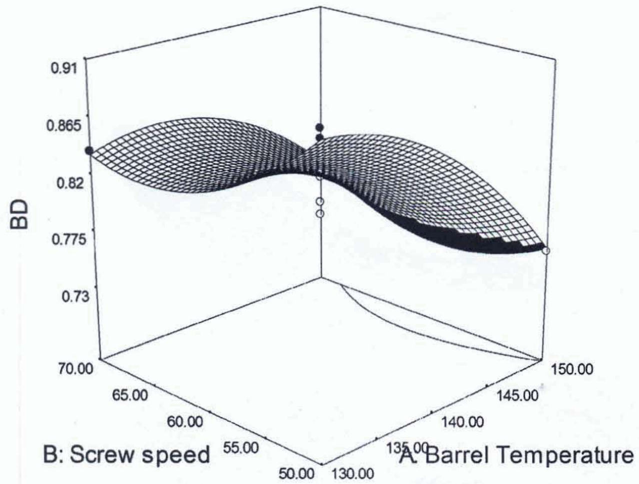

Figure 3: Response surface of Bulk density as a function of Barrel temperature and screw speed

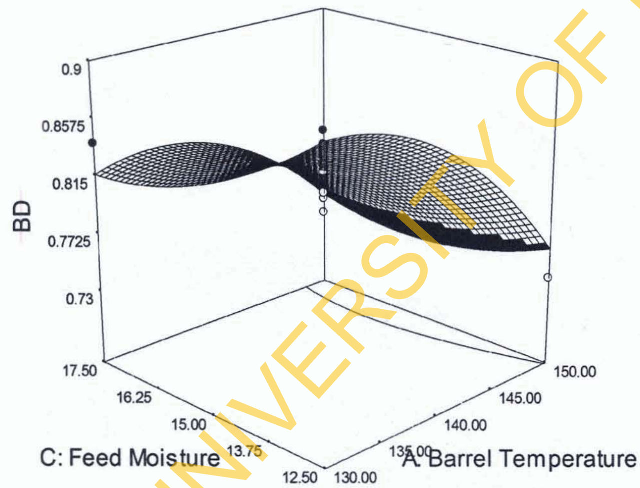

Figure 4: Response surface of Bulk density as a function of barrel temperature and feed moisture content

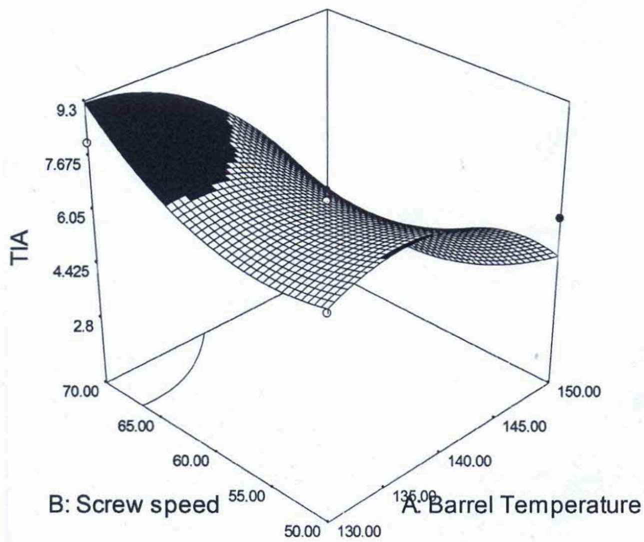

Figure 5: Response surface of trypsin inhibition activity of extrudate as a function of Barrel temperature and screw speed

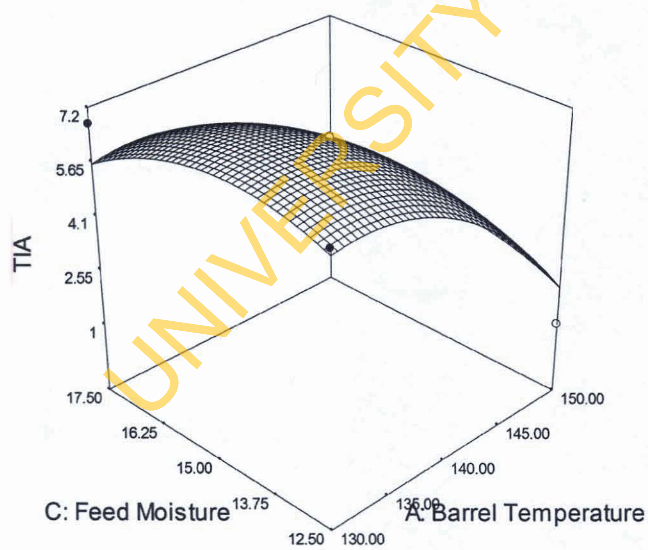

Figure 6: Response surface of extudate trypsin inhibition activity as a function of barrel temperature and feed moisture content