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0Unit Operations and Analyses for African Breadfruit Based Spaghetti-Type Products at Extreme Process Combinations

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Abstract: African breadfruit (*Treculia africana* Decne) was substituted with 5% fullfat corn and a range of 10-55% defatted soybean and extruded in a single screw Brabender extruder at process variable combinations determined in a 2nd order central composite design. Feed moisture and extruder screw speed were varied from 15-27% and 100-180 rpm, respectively. The design generated a total of 25 experiments from which low and high African breadfruit substitutions with corn and defatted soybean were selected and analyzed for compositional and organoleptic properties at minimum and maximum process variable combinations. Unit operations depending on the characteristic nature of seed type and extrusion process were carefully documented. Low or high substitution with 5% fullfat corn and either 10 or 55% defatted soybean, significantly ($p \leq 0.05$) increased protein or decreased carbohydrate by minimum of 22.21 and 3.96%, respectively. While Na, P, Mg and Fe decreased, K, Ca and Zn increased with substitutions in raw samples. Increase in Na and Zn at maximum process condition irrespective of sample extruded was significant ($p \leq 0.05$). Phytic acid, TIA and tannin contents, respectively decreased by 22.31, 83.50 and 90.06% for the control and 45.88, 91.47 and 92.55% for the high substitution at minimum process combination, while at maximum process conditions, a reduction by 27.70, 89.20 and 89.20% in phytic acid, TIA and tannin contents, respectively were recorded for the control. Panelists accepted the substituted products in all the attributes investigated better than the control. This was more significant ($p = 0.05$) in low substitution at minimum process variable conditions.

Key words: Soybean, African breadfruit, *Treculia africana*, extrusion cooking, central composite design, unit operations, spaghetti, trypsin inhibitor activity, phytic acid, tannin

INTRODUCTION

African breadfruit (*Treculia africana* Decne) a member of the family Moreceae and native of the East Indies was originally seen as a wild tropical rainforest plant but is presently well known source of food. It is now grown in most rain forest zones of Nigeria, Senegal, Sudan, Angola, Mozambique, Principle and Sao Tome Isands (Ajiwe *et al*., 1995).

As food habits and preferences of Nigerians are changing towards specialty food products due to increasing urbanization, the need to look inwards towards local food resources cannot be over emphasized. This is in an effort to reduce dependence on imported stuff. Consumption of specialty food products made from wheat has become so popular in the country that its total elimination from the food pattern of Nigerians will spell serious nutritional and socio-economic implications.

Consumption of blends of locally grown legumes and cereals on the basis of nutrient complementarity has been a tradition in Nigeria. Among these is the consumption of blends of dehulled whole seeds of African breadfruit and shelled milk-corn popular in Southern parts of Nigeria. In the homes, the seeds are roasted or boiled and eaten as porridges or with palm kernels as snacks. The potentials of African breadfruit as raw material for production of alcoholic (Okechukwu *et al*., 1984) or non-alcoholic (Ejiofor *et al*., 1988) beverages, bakery products (Guanu, 1993; Nwabueze and Atuonwu, 2006) and weaning formula with soybean (Ariahu *et al*., 1999), have been documented in literature as major scientific methods of African breadfruit seeds utilization.

Nigerians are familiar with and readily patronize extruded products such as spaghettis, macaronis and other noodles. Application of extrusion technology in Nigeria has been reported for soybean flour and its blends with cereals, roots, tubers and other low protein legumes since early 1980s (Dashiell *et al*., 1990; Iwe and Ngoddy, 1998; Lasekan and Akintola, 2002; Nwabueze, 2006a).

The objective of this research was to document unit operations involved in production of nutritionally fortified spaghetti-type products from African breadfruit and its substitutes with fullfat corn and defatted soybean. In addition extreme substitutions were to be selected and carried out included compositional analysis to determine

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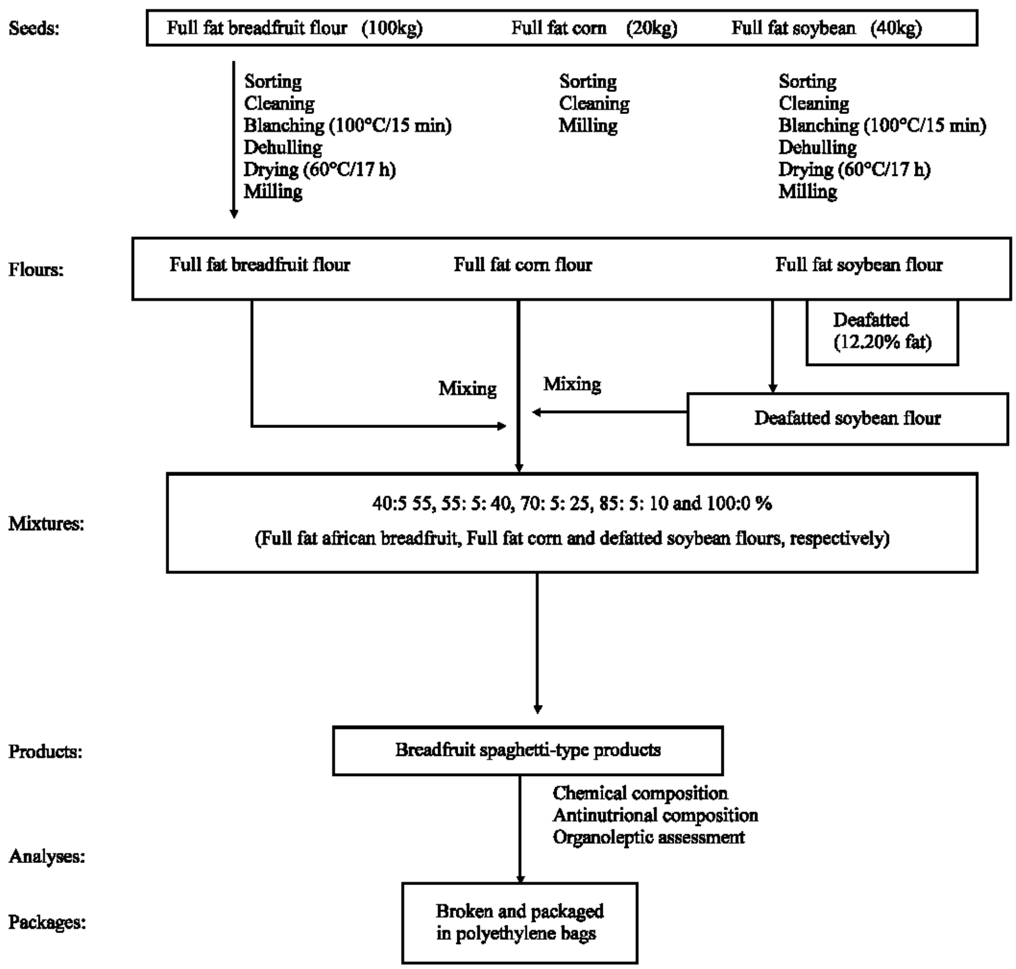

Fig. 1: Flow chart for unit operations in production of breadfruit seed based spaghetti-type products

Plate 1: Assemblage of raw materials unit operation: *Treculia* (Dehulled African breadfruit seeds), Maize (Corn grains), Soybean (Dehulled soybean seeds)

minimum and maximum process variable combinations. It is expected that this will not only broaden the adaptation of African breadfruit to industrial food enterprise but also save the crop from extinction, popularize and widen its scope of production and utilization, thus contributing to the well being and advancement of people of Nigeria.

Experimentation: Experimentation involved series of unit operations, which began with the raw materials as summarized in the Flow Chart (Fig. 1). African breadfruit (*Treculia africana* Decne), yellow corn and soybeans (Samsoy var.) (Plate 1) were used in the study. About 100, 20 and 4 kg of African breadfruit seeds, soybean and yellow corn were, respectively purchased from Mbano, Imo State and Yola, Adamawa State, Nigeria.

Pre-process operation: This unit operation involved subjecting each seed type to different unit operations depending on the characteristic nature of the seed type (Fig. 1). African breadfruit seeds were subjected to hot water blanching at 100°C for 15 min before cracking in a commercial attrition mill (Plate 2) for dehulling. Dehulled seeds were dried in Chirana type air convection oven (HS 20IA, Germany) at 60°C for 17 h. Dehulled dried seeds were subjected to further cleaning in a Vegvari Ferenc aspirator (OB 125 Budapest, Hungary) to produce the final seeds that were milled in a Brabender roller mill. The ensuing fine flour of 75µm particle size was stored for later use.

Yellow maize and soybeans were separately sorted and mechanically dry-cleaned in the aspirator unit. Soybean was further subjected to soaking in a stainless trough containing tap water for 18 h. The seeds were dehulled, partially dried in the sun before subjecting them to a 10 h oven drying. Yellow maize and dehulled soybean seeds were coarsely milled in a Brook Crompton laboratory hammer mill (DN 15 8QW, England) before finishing up in the roller mill to obtain fine flours of similar particle size (75 µm) as the breadfruit flour.

Soybean flour was later subjected to a defattening operation in excess hexane and centrifuged at 4000 rpm for 15 min. Resulting flour was oven dried evaporate excess hexane. All flours were stored in airtight plastic containers from which samples were collected for further study.

Mixing operation: Flours from these sources were thoroughly mixed in a Hobart mixer (A 200, England) in combination levels of 40-100% (African breadfruit), 0-55% (defatted soybean) and a constant 5% maize inclusion in each level in accordance with experimental design. Each combination was packaged in polyethylene bag and stored until needed.

Pre-extrusion operation: Major pre-extrusion operations carried out included compositional analysis to determine

Plate 2: Milling operation: Commercial attrition mill and cracked African breadfruit seeds

Plate 3: Extrusion unit operation: Single- screw Brabender extruder for African breadfruit based spaghetti-type products

Plate 4: Post-handling operation: Spaghetti-type products as they emerged from extruder die orifice

Plate 5: Packaging operation: Broken spaghetti-type products packaged in polyethylene bag

among other parameters the initial moisture level of each combination level. Based on the result, combination levels were hydrated by material balance to 15-27% (Nwabueze, 2006a).

Extrusion operation: African breadfruit and combination levels were extruded in a single-screw pilot type Brabender extruder (DCE 330, Brabender Instruments Inc., South Hackensack, NJ) (Plate 3) at varying screw speed (100-180 rpm) (Nwabueze, 2007). African breadfruit and combination levels at extreme process conditions of 15% moisture (minimum) and 27% (maximum) and screw speed of 100 rpm (minimum) and 180 rpm (maximum) were selected for analyses as specialty products.

Post extrusion operation: Extrudates emerged as spaghetti-type products from the orifice die (Plate 4). The strands were manually broken into process. All the products were dried in the oven at 60°C for 10 h before packaging in polyethylene bags for analysis and evaluation (Plate 5).

Compositional analysis: Analyses carried out on raw samples and products included proximate (AOAC, 1995), minerals (Lawal, 1986; Attia *et al.*, 1994) and antinutritional factors including phytic acid (Davis and Reid, 1979), trypsin inhibitor activity (Kakade *et al.*, 1974) and tannin (Pearson, 1976).

Organoleptic assessment: A 30-member semi-trained panelists drawn from staff and students' population of Michael Okpara University of Agriculture, Umudike, Nigeria, assessed the products. Organoleptic properties assessed included appearance, aroma, texture, taste and overall acceptability on a 9-point hedonic scale according to Lawless and Heymann (Lawless and Heymann, 1998). The 9-point scale was summarized as dislike extremely, 5 = neither like nor dislike and 9 = like extremely (Iwe, 2001).

Experimental design: A 2nd order central composite rotatable response surface for K = 3 was adapted as modeled by Snedecor and Cochram (1980) and express mathematically as

$$y = b_0+b_1X_1+b_2 X_2 +b_3 X_3 +b_{11}X^2_1+b22X^2_2+b33X^2_3 +b_{12}X_1X_2 +b_{13} X_1X_3 +b_{23} X_2X_2X_3+e$$

Where y is response function, bo is constant, X_3 is extruder screw speed and e is random error term.

This study generated a total of 25 experiments from which low and high African breadfruit substitutions with defatted soybean at minimum and maximum process variable combinations were selected for further study.

RESULTS AND DISCUSSION

Proximate composition of raw and extruded samples of African breadfruit at low and high substitutions with corn and soybean: Table 1 shows the proximate composition of raw and extruded control (100% African breadfruit) and African breadfruit substituted with low/high levels of fullfat corn and defatted soybean. With 15.76, 11.45 and 60% protein, fat and carbohydrate, respectively (Table 1a), African breadfruit seed cannot be

Table 1: Chemical composition of low and high African breadfruit substitutions with defatted soybean at minimum and maximum process variable combinations

(a) Raw samples	Protein	Fat	Ash	Carbohydrate
Control	15.76[a]	11.45[a]	3.00[a]	60.59[a]
Low substitution	19.26[b]	1.45[a]	2.00[a]	58.19[b]
High substitution	35.02[c]	13.80[b]	2.50[a]	40.88[c]

	Minimum process conditions				Maximum process conditions			
(b) Product	Cp	Fat	Ash	Carb	Cp	Fat	Ash	Carb
Control	17.52[a]	11.10[a]	1.00[a]	63.18[a]	18.38[a]	10.90[a]	3.00[a]	61.92[a]
Low substitution	21.90[b]	10.15[b]	2.00[b]	59.15[b]	22.76[b]	8.90[b]	3.00[a]	58.34[b]
High substitution	33.28[c]	13.25[c]	3.00[c]	43.07[c]	32.40[c]	12.25[c]	3.00[a]	44.95[c]

Extruded at minimum (15% and 100 rpm) and maximum (27% and 180 rpm) process variable conditions of feed moisture and screw speed, respectively. Control = zero substitution or 100% African breadfruit; Low/High = substitution of African breadfruit with 5% corn and defatted soybean at 10/ 55%, respectively. Means with the same superscripts in the same column are not significantly different ($p \leq 0.05$)

Table 2: Mineral composition of low and high African breadfruit substitutions with defatted soybean at minimum and maximum process variable combinations

(a) Raw samples	K	Na	P	Ca	Mg	Zn	Fe
Control 774^{a}	9.0^{a}	160^{a}	83.33^{a}	312.14^{a}	0.161^{a}	333.60^{a}	
Low substitution	756^{a}	8.0^{b}	150^{a}	95.83^{a}	309.91^{b}	0.484^{b}	31275^{b}
High substitution	1160^{b}	7.0^{c}	120^{b}	187.50^{b}	307.86^{b}	0.484^{b}	291.90^{c}

(b) Product	Control		Low substitution		High substitution	
Process conditions:	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Minerals						
K	684.0^{a}	900.0^{b}	756.0^{a}	792.0^{b}	846.0^{a}	756.0^{b}
Na	8.0^{a}	8.5^{b}	8.0^{a}	9.5^{b}	9.0^{a}	10.0^{b}
P	100.0^{a}	110.0^{a}	104.0^{a}	125.0^{b}	85.0^{a}	80.0^{b}
Ca	150.0^{a}	129.2^{b}	58.3^{a}	100.0^{b}	87.5^{a}	79.2^{b}
Mg	312.3^{a}	315.7^{a}	310.4^{b}	314.2^{b}	299.5^{c}	295.4c
Zn	0.3^{a}	0.6^{b}	0.2^{a}	0.5^{b}	0.3^{a}	0.6^{b}
Fe	125.1^{a}	271.1^{b}	271.1^{a}	166.8^{b}	187.7^{a}	271.1^{b}

Extruded at minimum (15% and 100 rpm) and maximum (27% and 180rpm) process variable conditions of feed moisture and screw speed, respectively. Control = zero substitution or 100% African breadfruit; Low/High = substitution of African breadfruit with 5% corn and defatted soybean at 10/ 55%, respectively. Means with the same superscripts in the same row and substitution are not significantly different ($p \le 0.05$)

Table 3: Anti nutritional composition of low and high African breadfruit substitutions with defatted soybean at minimum and maximum process variable combinations

(a) Raw samples	Phytic acid (mg 100 g^{-1})	TIA (TIU mg^{-1})	Tannin (mg 100 g^{-1})
Control	129.50^{a}	10.00^{a}	17.40^{a}
Low substitution	153.00^{b}	10.60^{a}	30.20^{b}
High substitution	177.21^{c}	21.80^{b}	30.60^{b}

(b) Product	Minimum process conditions			Maximum process conditions		
	Phytic acid (mg 100 g^{-1})	TIA (TIU mg^{-1})	Tannin (mg 100 g^{-1})	Phytic acid (mg 100 g^{-1})	TIA (TIU mg^{-1})	Tannin (mg 100 g^{-1})
Control	100.61^{a}	1.65^{a}	1.73^{a}	93.60^{a}	1.08^{a}	1.88^{a}
Low substitution	87.65^{b}	1.55^{a}	1.73^{a}	109.96^{b}	1.83^{b}	1.59^{b}
High substitution	95.91^{c}	1.86^{b}	2.31^{b}	119.31^{c}	2.00^{c}	2.03^{c}

Extruded at minimum (15% and 100 rpm) and maximum (27% and 180rpm) process variable conditions of feed moisture and screw speed, respectively. Control = zero substitution or 100% African breadfruit; Low/High = substitution of African breadfruit with 5% corn and defatted soybean at 10/ 55% , respectively. Means with the same superscripts in the same column are not significantly different ($p \le 0.05$)

Table 4: Organoleptic assessment of low and high African breadfruit substitutions with defatted soybean at minimum and maximum process variable combinations

	Minimum process conditions					Maximum process conditions				
	Ap	Ar	Te	Ta	Ov	Ap	Ar	Te	Ta	Ov
Control^{a}	3.90^{a}	5.10^{a}	5.10^{a}	5.20^{a}	5.20^{a}	3.30^{a}	4.40^{a}	4.20^{a}	4.30^{a}	3.90^{a}
Low substitution^{b}	6.60^{b}	5.70^{a}	6.40^{b}	5.90^{a}	6.40^{b}	3.70^{b}	5.00^{b}	5.10^{b}	4.60^{b}	4.70^{b}
High substitution^{c}	5.40^{c}	5.60^{a}	6.30^{b}	5.20^{a}	5.50^{b}	6.10^{c}	5.60^{b}	6.90^{c}	5.70^{c}	6.30^{c}

Extruded at minimum (15% and 100rpm) and maximum (27% and 180rpm) process variable conditions of feed moisture and screw speed, respectively. Ap is appearance, Ar is aroma, Te is texture, Ta is taste and Ov is overall acceptability. Control = zero substitution or 100% African breadfruit; Low/High = substitution of African breadfruit with 5% corn and defatted soybean at 10/ 55% , respectively. Means with the same superscripts in the same column are not significantly different ($p \le 0.05$)

classed as low food nutrient resource. In addition, low or high substitution with 5% fullfat corn and either 10 or 55% defatted soybean, significantly ($p \le 0.05$) increased or decreased protein/carbohydrate by minimum of 22.21/3.96%, respectively. Addition of fullfat corn and defatted soybean to African breadfruit amounts to food fortification, providing some level of complementarities. This further raises the nutritional status of African breadfruit as with some low protein foods (Iwe *et al*., 2003; Asp and Bjorck, 1989) and makes such blending relevant in solving malnutrition problems still prevalent in most developing countries.

The proximate composition of extrusion-cooked products though showed higher protein and carbohydrate values, followed similar pattern as with the unextruded samples (Table 1b). The general reduction in fat in extrusion-cooked products was due mainly to the high oil loss as drips and also to possible thermal degradation of lipids during the extrusion process. The high temperature range in the extruder barrel (120-170°C), coupled with increase in feed moisture (15 to 27%) and screw speed (100 to 180 rpm) had a positive degradation effect on carbohydrate components of amylose and amylopectin by chain splitting.

Mineral composition of raw and extruded samples of African breadfruit at low and high substitutions with corn and soybean: Mineral composition of raw and extruded samples of African breadfruit at low and high substitutions with fullfat corn and defatted soybean is shown in Table 2. It shows that mineral elements were well distributed in the blends whether extruded or not. Some of these distributions were either significantly ($p \leq 0.05$) or non-significantly ($p>0.05$) affected by low or high substitutions of African breadfruit with 5% fullfat corn and 10/55% defatted soybean. While Na, P, Mg and Fe decreased, K, Ca and Zn increased with the substitutions in the raw samples (Table 2a) indicating a nutritional benefit of blending. Extrusion of both control and substitutes showed consistent significant ($p \leq 0.05$) increase in Na and Zn at maximum process condition (27% feed moisture and 180 rpm screw speed), irrespective of sample extruded (Table 2b). Other mineral elements had no significant ($p>0.05$) trend of change due to extrusion cooking.

Antinutritional factors in raw and extruded samples of African breadfruit at low and high substitutions with corn and soybean: Antinutritional factors in Table 3a showed that substituted samples significantly ($p \leq 0.05$) differed from the control or 100% African breadfruit. They increased towards high substitution by 36.84, 118 and 75.86% for phytic acid, TIA and tannin, respectively. This implied an increase in antinutritional properties as defatted soybean increased or as African breadfruit concentration in the blend decreased.

At minimum process conditions (15% feed moisture and 100rpm screw speed), phytic acid, TIA and tannin contents, respectively decreased by 22.31, 83.50 and 90.06% for the control and 45.88, 91.47 and 92.55% for the high substitution (5% fullfat corn and 55% defatted soybean) (Table 3b). At maximum process conditions (27% feed moisture and 180 rpm screw speed), a reduction by 27.70, 89.20 and 89.20% in phytic acid, TIA and tannin contents, respectively were recorded for the control, while higher values of 32.67, 90.83 and 93.37% were recorded for the high African breadfruit substitution. Lower reduction in antinutritional factors at maximum process conditions for the high substitution could be attributed to dough short residence time in the extruder barrel due to high screw speed coupled with high lubricating effect of the high moisture content. Effect of extrusion cooking on antinutritional factors particularly the TIA is dependent on a number of factors including process temperature, length of heating, particle size, screw speed and residence time (Nwabueze, 2007). This calls for a careful selection of appropriate processing methodology that will completely eliminate these factors or at least reduce them to safe levels without impairing nutritional quality of the food.

Organoleptic assessment of African breadfruit at low and high substitutions with corn and soybean: Organoleptic assessment of extruded African breadfruit at low and high substitutions with corn and soybean shown in Table 4 indicates that Panelists better accepted the substituted products in all the attributes investigated than the control or 100% African breadfruit. Whenever any cereal and/ or high protein feed is extrusion cooked, the feed is texturally and histologically restructured. Substitution of African breadfruit with defatted soybean amounted to high protein addition into the feed (Table1). In production of starch-based products small percentage of additives may greatly alter the quality of the final product especially in terms of textural characteristics (Chang, 1986; Villota and Hawkes, 1987), which could have contributed in some measures to the observed result in this research.

Extruders as chemical (Cheftel, 1986) or bio (Zheng and Wang, 1994; Rizvi *et al*., 1995) reactors encourage many physical and chemical transformations of biopolymers and food mixes at high temperatures and pressures for relatively short residence times and in most cases at low moisture contents. This in turn causes changes in properties of the extruded products. At minimum process variable conditions (15% feed moisture and 100rpm screw speed), low substitution of African breadfruit (5% fullfat corn and 10% defatted soybean) was most significantly ($p \leq 0.05$) acceptable while at maximum process conditions (27% feed moisture and 180rpm screw speed), high substitution (5% fullfat corn and 55% defatted soybean) was most significantly ($p \leq 0.05$) acceptable. Moisture content of feed has an effect on extruder capacity by controlling the frictional resistance of the feed being conveyed through the extruder. The feed at minimum process variable conditions of 15% moisture had higher frictional resistance than the one at maximum process variable conditions with high moisture.

CONCLUSIONS

Specialty products from African breadfruit and its substitutes with 5% corn and 10-55% soybean were produced at minimum (15% mc and 100 rpm screw speed) and maximum (27% mc and 180 rpm screw speed) process variable conditions. Unit operations involved subjecting each seed type to different treatments depending on the characteristic nature of the seed type and ending with extrusion into spaghetti-type snacks.

Low or high African breadfruit substitution significantly ($p \leq 0.05$) increased or decreased protein/carbohydrate by minimum of 22.21/3.96%, respectively. Analysis of mineral composition showed a good distribution in the blends whether extruded or not. Extrusion of both control and substitutes showed consistent significant ($p \leq 0.05$) increase in Na and Zn at maximum process condition. Antinutritional factors increased towards high substitution by 36.84, 118 and 75.86% for phytic acid, TIA and tannin, respectively. At maximum process conditions, a reduction by 27.70, 89.20 and 89.20% in phytic acid, TIA and tannin contents, respectively were recorded for the control and 32.67, 90.83 and 93.37% for the high African bread substitution following extrusion cooking. The specialty products were generally acceptable by Panelists with the substitutes being better accepted than the control.

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