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Effects of Extrusion-Cooking on the Nutrient and Anti-Nutrient Composition of Pigeon Pea and Unripe Plantain Blends

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ABSTRACT

The effects of extrusion cooking on the nutrient and anti-nutrient composition of raw and extruded blends of pigeon pea and unripe plantain flours were evaluated. Pigeon pea seeds were cleaned and processed into flour while unripe plantain was peeled, sliced, dried and milled into flour separately and sieved to pass 0.85mm mesh. The moisture content of the flours was determined. Unripe plantain flour was added to pigeon pea flour at 25% levels of substitution. The moisture content of the blends was adjusted to 25% levels. The blends were extruded using a Brabender laboratory single-screw extruder (Duisburg DCE 330 model) at 120rpm and temperature of 100^0c. The proximate composition, minerals, amino acid profile and some vitamins of raw and extruded samples were determined. Antinutrients (Phytate, saponnis, oxalate, tannin, trypsin inhibitor, lectin and hydrogen cyanide content) of raw and extruded samples were also estimated. Results of proximate composition, showed a significant ($P<0.05$) increase in fat content (1.97%) and energy value (1420 kj/100g), while marginal decrease was noticed in protein (22.98%), ash (3.72%) and crude fibre (7.04%). The results of mineral content showed significant ($p<0.0.5$) increase in the extrudate iron (5.02mg/100g) zinc (4.35mg/100g) calcium (32.35mg/100g) and potassium (333.07mg/100g). Vitamin content was significantly ($P<0.05$) reduced in the extrudate Vitamin A (4.29mg/100g), Vitamin B_1 (4.03mg/100g), Vitamin B_2 (0.40mg/100g), and Vitamin C (0.01mg/100g). The amino acid profile was affected by extrusion process but the essential amino acids in the extrudate met requirements for adults. Blending pigeon pea and unripe plantain flour at 25% of unripe plantain flour substitution resulted in the reduction of anti-nutrients evaluated. Extrusion cooking further considerably lowered these anti-nutrients to safer levels.

Keywords: *pea, unripe plantain flour, blending, extrusion-cooking.*

INTRODUCTION

The Food and Agricultural Organization (FAO) of the World Health Organization (WHO) estimated that between 1990 and 1992, 204 million people in sub-suharan Africa (41% of the population of the region) were chronically undernourished (Ifeoma *et al.*, 2010). Inadequate intake of protein in developing countries has led to various forms of malnutrition in both children and adults (Okpala *et al.*, 2011).

It has been reported that in developing countries such as Nigeria protein malnutrition persists as a principal health problem among children below the age of five (UNICEF, 1996). Therefore, the need to find inexpensive sources of protein food of good quality cannot be over emphasized. The protein calorie sources of vegetable origin have been proposed as a solution to this problem (Abioye *et al.,* 2011). Pigeon pea (*Cajanus cajan*) is a legume which forms important component of the diets in many developing countries (Aron, 2002). Legumes are usually rich in proteins, essential amino acids and minerals, and are used to supplement other foods (Etonihu *et al.,* 2009).

Among the cereal-based diets of Asians, *Pigeon pea* is consumed in various forms and supplies about 30-49% of the protein needs thereby contributing to a nutritionally balanced human food (Jambunathan and Sigh, 1981).

Plantain (*Musa spp*) is a popular dietary staple due to its versatility and good nutritional value (Abioye *et al.,* 2011). In Nigeria and many African countries, plantains are used as an inexpensive source of calories (Akubor *et al.,* 2003). The fruit or pulps of unripe or half ripe plantains are roasted on heated charcoal. The resultant product is usually consumed with other delicacies such as roasted plums, avocado, roasted fish, and sometimes with combination of hot stew (Adeniji *et al.,* 2007). It is also consumed mainly as snacks in the form of chips, *Dodo Ikire* e.t.c (Abioye *et al.,* 2011). Unripe plantain is traditionally processed into flour in Nigeria and in other West and Central African Countries (Ukhum and Ukpebor, 1991). It is however gradually finding applications in weaning food formulation and composite flour preparations (Olaoye *et al.,* 2006).

Blending of pigeon pea and unripe plantain would provide a wide range of high protein, calories, and micronutrients if properly processed. Furthermore, blending of pigeon pea high in protein (mostly essential amino acids) and unripe plant in rich calories and dietary minerals would provide reasonable levels of complementarily. The retention of these essential nutrients would be enhanced through the application of extrusion cooking processes (Iwe, 2003). Extrusion cooking has some unique features compared to other heat process (Filli *et al.,* 2010). Iwe (2003) explained that precooking would be important in developing countries where quick cooking saves scarce fuel and simplifies preparation. Again, a precooked product that requires minimal further cooking before serving is obtained from extrusion cooking. To achieve such aims of precooking targeting enzyme denaturation, antinutrient inhibition, microbial inactivation, general product acceptability e.t.c, extrusion cooking presents the best option (Anuonye *et al.,* 2009). The deleterious effects of anti-nutrients are widely reported. Fava beans (Vicia faba,L.) produces severe haemolytic anemia in G6PD deficiency,hydrocyanic acid common in cassava and Lima beans is a potent inhibitor of the electron transport chain,etc (Osagie,1998). Extrudates are microbiologically safe, can be stored for long periods because of low moisture content (Filli and Nkama, 2007). The objective of this present work was to evaluate the impact of extrusion cooking on the proximate and anti-nutrient composition of extruded mixtures of pigeon pea and unripe plantain flour.

MATERIALS AND METHODS

Mature pigeon pea seeds were obtained from New Central Market Minna, Niger State, Nigeria. Dried seeds (500g) were sorted, washed, tempered and cracked to dehull the seeds. The dehulled mass was winnowed manually. The resulting grit was ground in a laboratory attrition mill to fine flour and sieved to pass sieve mesh of 0.85mm. Unripe plantain fingers were obtained from Ebo Village in Lapai Local Government Area of Niger State, Nigeria. Twenty fingers of the fruit sample were washed and peeled manually using stainless kitchen knife. The pulps were sliced longitudinally to about 15mm thickness. The slices were steam blanched in $NaHS0_4$ for 5minutes to prevent browning. The slices were sun dried for 3 days at 35-40^{o}c and milled using a laboratory attrition mill to fine flour that passed through a laboratory sieve mesh of 0.85mm. The moisture content of the flour was determined and adjusted to 25% according to methods described by Anuonye *et al.,* (2007). The unripe plantain flour was blended with the pigeon pea flour at 25% levels of substitution. Extrusion cooking was performed in a single screw extruder, (Model Brabender Duisburg DCE-330 Germany) equipped with a variable speed D-C drive unit, and strain guage type torque meter. The extruder was fed manually through a screw operated conical hopper at a constant speed of 80rpm which ensures the flights of the screw fills and avoiding accumulation of the materials in the hopper. The extruder barrel has a 20mm diameter with length to diameter ratio (L.D) of 20:1. The extruder had variable screws and heater with a fixed diameter of 2mm and length. After steady state conditions were attained emerging extrudates were collected and air dried at room temperature. The extrudites were milled into flour using attrition mill to pass screen size of 0.85mm and kept in airtight containers for further analysis

PROXIMATE ANALYSIS

Percent moisture, crude fat, ash, crude fiber and crude protein contents were determined using the methods of Association of Official Analytical Chemists (AOAC, 2006). Amino acid profile was determined as described by Spackman *et al.,* (1958). The carbohydrate was calculated by difference. Gross energy value (KJ/100g DM) was calculated as described by Ekanayake *et al.,* (1990), mineral contents and Vitamin were evaluated in raw and extruded samples according to AOAC (2006). Samples were analyzed in triplicates.

ANALYSIS OF ANTI-NUTRITIONAL FACTORS

The trypsin inhibitor was determined according to Arntified et al., (1985). Hydrogen cyanide was determined by the alkaline picrate colorimetric method of Balagopalam *et al.,* (1988) Tanins, phytate, saponin and oxalate were determined using the method described by Nwosu (2010). Lectin was determined using the method employed by Jimoh *et al.,* (2011).

STATISTICAL ANALYSIS

Data collected were analysed using Analysis of Variance (ANOVA) with the Statistical Package for Social Sciences (SPSS) for windows version 16. Results were expressed as mean ± SEM.

RESULTS AND DISCUSSION

Table:1 presents the proximate composition of both raw samples and the extruded blend. There was no significant (P>0.05) difference in the moisture content of the sample.

Table. 1: Proximate Composition of Raw and extruded blend samples.

	Raw Samples		
Nutrient	Pigeon pea	Unripe plantain	Extruded blend
Moisture Content (%)	8.75 ± 0.05[b]	10.21 ± 0.20[a]	7.99 ± 0.02[b]
Fat Content (%)	1.81 ± 0.02[a]	0.98 ± 0.04[b]	1.97 ± 0.03[a]
Protein (N% x 6.25)	23.78 ± 0.04[b]	6.57 ± 0.02[c]	22.98 ± 0.03[a]
Ash Content (%)	3.89 ± 0.04[b]	4.42 ± 0.04[a]	3.72 ± 0.02[b]
Crude fibre (%)	8.45 ± 0.03[a]	3.93 ± 0.05[c]	7.04 ± 0.01[b]
Carbohydrate (by diff) %	53.32 ± 0.87[b]	62.95 ± 0.06[a]	53.78 ± 0.04[b]
Energy value (KJ/100g)	1377.67 ± 0.01[b]	1218.10 ± 0.04[c]	1420.65 ± 0.01[a]

Values are means and standard deviations of three determinations.

Values not followed by the same superscript in the same row are significantly different (p<0.05).

The low moisture content will give the product a long shelf life as reported by Aremu *et al.,* (2006). There was a significant (P<0.05) increase in the fat content of the extruded blend. This shows that blending had improved the proximate composition as reported by Anuonye *et al.,* (2009), and Obatolu (2002). The protein content of extrudates decreased but the decrease was not significant (P>0.05). This trend was also observed by Anuonye *et al.,* (2009). This decrease might be due to the gelatinization effect of the extrusion processing (Rampersad *et al.,* 2003). There was no significant (P>0.05) difference in the values of ash, fibre and carbohydrate contents in the extrudates. This might be due to the level of the dilution as reported by Anuonye *et al.,* (2009) in the case of Acha (*Digitaria exillis*)/Soybean flour blend. Reduction in protein content led to increase in the calorific value. This was expected and was in conformity with reported trends (Anuonye *et al.,* 2009; Iwe *et al.,* 2001). Table 2 shows the result of dietary mineral composition of raw samples and extruded blends. There were significant (P<0.05) differences.

Table. 2: Mineral composition (mg/100g) of raw samples and extruded blend.

Mineral composition	Pigeon pea	Unripe plantain	Extruded blend
Fe	4.11 ± 0.00[b]	3.52 ± 0.00[c]	5.02 ± 0.00[a]
Zn	4.32 ± 0.00[a]	2.16 ± 0.00[b]	4.35 ± 0.00[a]
Cu	25.01 ± 0.00[a]	15.25 ± 0.00[b]	25.65 ± 0.00[a]
Mg	135.57 ± 0.00[a]	124.42 ± 0.00[b]	136.57 ± 0.00[a]
Ca	26.11 ± 0.00[b]	33.35 ± 0.00[a]	32.35 ± 0.00[a]
K	117.30 ± 0.00[b]	325.38 ± 0.00[a]	333.07 ± 0.00[a]
Na	95.04 ± 0.00[b]	120.83 ± 0.00[a]	98.21 ± 0.00[b]

Values are means and standard deviations of three determinations.
Values not followed by the same superscript in the same row are significantly different (p<0.05).

The result of Vitamin content of raw samples and extruded blend is shown in (table 3). Extrusion cooking caused significant (P<0.05) decrease in the Vitamin content of the extrudate.

Table. 3: Vitamin contents (mg/100g) of raw samples and extruded blend.

Vitamin (mg/100g)	*Pigeon pea*	Unripe plantain	Extruded blend
A	11.53 ± 0.02	12.55 ± 0.00	4.29 ± 0.01
B_1	15.82 ± 0.02	16.45 ± 0.00	4.03 ± 0.01
B_2	0.88 ± 0.02	0.43 ± 0.00	0.40 ± 0.04
C	0.04 ± 0.00	0.08 ± 0.00	0.01 ± 0.00

Values are means and standard deviations of three determinations.
Values not followed by the same superscript in the same row are significantly different (p<0.05).

The extrudates had higher values for mineral composition than individual raw samples which show that fortification had improved the nutritional value of extrudates. This increase has been attributed to screw wear in the extruder (Artz *et al.,* 1992). This trend is in conformity with earlier reports of Harper (1988); Anuonye *et al.,* (2009). The reason may be due to heat sensitivity and oxidation tendency of this class of nutrients. Table 4, shows the result of amino acid composition of raw samples and extruded blends. Extrusion cooking resulted in reduction of most of the amino acids assessed while increment was noticed in glutamic acid in the extrudate.

Table. 4: Amino acid profile of raw *Pigeon pea*, Unripe plantain and extruded samples (g/100g).

Amino acid	Raw *Pigeon pea*	Unripe plantain	Extruded blend	FAO(g/100 g protein) children	Adult
Lysine	7.80	2.31	3.25	5.50	2.40
Histidine	3.67	0.88	1.66	1.40	-
Arginine	5.88	3.00	5.02	-	-
Aspartic acid	11.58	1.00	6.02	-	-
Threonine	3.12	2.05	2.11	4.00	1.40
Serine	3.59	4.10	2.32	-	-
Glutamic acid	9.24	3.08	12.12	-	-
Proline	3.18	3.06	1.91	-	-
Glycine	3.08	2.08	3.02	-	-
Alanine	3.80	0.40	2.82	-	-
Cysteine	1.19	3.49	0.66	-	-
Valine	5.85	0.39	3.02	5.00	2.00
Methionine	1.19	0.78	0.70	-	-
Isolencine	3.47	1.02	2.29	4.00	2.00
Leucine	6.47	2.42	5.11	7.00	2.80
Tyrosine	2.63	6.63	1.77	-	-
Phenylalanine	6.15	0.76	5.16	-	-

Source: FAO (1970)

Protein denaturation due to heating leading to transamination and deamination reactions and hence reduction in amino acids have been reported by Yaqoub *et al.,* (2008). Comparing the amino acid of the samples with FAO (1970) recommended intake for adults and children, values obtained from the extruded blend meets the essential amino acid requirement of adults while children requirements are also substantially present.

The results of the antinutritional components of raw samples and extruded blend are shown in table 5. Extrusion cooking reduced the phytate level by 68.80% from (0.86% to 0.26%). It would be expected that lowering this compound should enhance the bioavailability of such minerals as zinc and iron in the extrudates as phytic acid has been implicated in making these minerals unavailable as reported by Anuonye *et al.,* (2009). The levels of tannin was reduced from 0.98% to 0.38% in extrudates or 61.22%. This showed that extrusion cooking caused significant (P<0.05) decrease in this antinutrient. Tannins form insoluble complexes with proteins thereby decreasing the digestibility of proteins (Uzoechina, 2007). Tannins also decrease palatability, cause damage to intestinal tract, and enhance carcinogenesis (Makkar and Becker, 1996). The saponin content was significantly (P<0.05) reduced from 0.58% in raw sample blends to 0.09% in the extrudate which indicates 84.48% reduction. Saponins increase permeability of small intestinal mucosa cells thereby inhibiting nutrient transport (Jimoh *et al.,* 2011). They however can lower plasma cholesterol concentrations (Oakenfull et al, 1979).

Table. 5: Levels of some Anti-nutrients in raw samples and extruded blend.

RAW SAMPLES			
Antinutrients	***Pigeon pea* and unripe plantain blend (75:25)**	**Extruded blend (75.25)**	**(%) Decrease in antinutrients in extruded samples**
Tannins (%)	0.98 ± 0.00	0.38 ± 0.00	61.22
Phytate (%)	0.86 ± 0.00	0.26 ± 0.00	69.76
Saponin (%)	0.58 ± 0.00	0.09 ± 0.00	84.48
Oxalate (%)	0.72 ± 0.00	0.04 ± 0.00	94.44
Trypsin inhibitor TIU (mg/g)	0.46 ± 0.00	0.07 ± 0.00	84.78
Hydrogen cyanide HCN (mg/g)	9.85 ± 0.00	2.05 ± 0.00	78.18
Lectin (%)	0.68 ± 0.00	0.28 ± 0.00	58.82

The extrusion process significantly (P<0.05) reduced oxalate content by 94.44%. Oxalate may be present as oxalic acid or as insoluble calcium oxalate which when present in high concentration in diet may increase the risk of renal calcium absorption (Osagie, 1998).

Trypsin inhibitor was reduced significantly (P<0.05) from 0.46mg/g in the raw sample blends to 0.07mg/g or 84.78% in the extrudates. The thermoliability of Trypsin inhibitor implies that protein digestibility will not be hampered when the product is consumed as reported by Iorgyer *et al.,* (2009). Hydrogen cyanide (HCN) in the raw samples was reduced significantly (P<0.05) from 9.8mg/kg to 2.05mg/kg in the extrudate equivalent to 78.18% reduction. Iorgyer *et al.,* (2009) has reported that hydrogen cyanide is heat labile and volatile which confirms the reduction after subjecting the sample to extrusion process. Consumption of foods containing cyanogens could result in acute or chronic toxicity. The Lectin level was significantly (P<0.05) reduced from 0.68% in the raw samples to 0.28% in the extrudates or 58.82% reduction. It is remarkable that lectins are usually reported as being heat labile, their stability however vary between plant species as reported by Almeida *et al.,* (1991). Lectins are proteins with the unique ability to bind specific sugars or glycol proteins. This results into agglutination (clumping) of red blood cells from various species of animals as reported by Osagie (1998).

CONCLUSION

Extrusion cooking affected the nutrients especially the proximate composition while the amino acid composition in the extrudate contain amounts that met adult recommended levels. The extrusion process considerably reduced most of the antinutrients evaluated. The extrudate has good potential as a cheap source of ready-to-eat diet rich in nutrient, safe in antinutrients and could be utilized to improve food security against malnutrition.

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