FERMENTATION AND EXTRUSION EFFECTS ON NUTRITIONAL AND ORGANOLEPTIC COMPOSITIONS OF UNRIPE PLANTAIN AND PIGEON PEA BLENDS

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ABSTRACT

This research investigated effects of fermentation and extrusion on unripe plantain and pigeon pea blends. The samples were blended and prepared in three combinations (A=100g unripe plantain; B= 70g unripe plantain: 30g pigeon pea; C= 50g unripe plantain: 50g pigeon pea) and sectioned into four group (i.e. group 1 = preconditioned and fermented; group 2 = extruded; group three = fermented and extruded; and group 4 = unfermented/unextruded). Semi-solid state fermentation method was employed to ferment the blended samples for 96 hours. The physicochemical parameters (i.e pH, temperature and total titratable acidity) of these fermented samples were evaluated. The total microbial counts include; 9 bacteria, 2 yeasts and 4 molds were isolated and identified as; *Bacillus subtilis*, *Bacillus cereus*, *Micrococcus luteus*, *Staphylococcus aureus*, *Lactobacillus plantarum, Lactobacillus fermentum*, *Leuconostoc mesenteroides*, *Lactobacillus mali*, *Streptococcus lactis, Saccharomyces cerevisiae, Candida utilis, Aspergillus niger, Aspergillus fumigatus, Aspergillus candidus,* and *Mucor hiemalis.* There were significant variations in the values of pH and total titratable acidity (TTA) during fermentation. This was also same for the proximate contents of the fermented and extruded flour blends when contrasted with the raw flour blends. The fermented unextruded group 1 (11.73±0.01%) has the highest moisture contents and least in the raw sample B (6.34±0.00%). The raw flour blends protein content increased from 2.57±0.03 to 10.17±0.00% and from 2.58±0.02 to 16.27±0.01% in the fermented extruded blends. The carbohydrate content in the raw flour blends was highest (67.97±0.02 to 74.32±0.00%) and least in fermented unextruded samples (38.28±0.01 to 62.72±0.01%). The fat content was highest in the fermented unextruded blends (2.52±0.01 to 6.33±0.00%) and least in raw blends (1.33±0.02 to 2.01±0.02%). The sensory evaluation of the samples showed a good preference for fermented-extruded samples. Findings from this research have established that fermented and extruded unripe plantain and pigeon pea blend enhanced nutritional value of food.

Keywords: Unripe plantain, pigeon pea, fermentation, extrusion

1. Introduction

Studies have shown that fermentation and extrusion improve the nutritional value of weaning foods by reducing the water-binding capacity of cereal flour (Ojokoh and Temitope, 2017). Amadou *et al*. (2011) reported extrusion as an effective treatment to better cereals' nutritional quality. Fermentation is among aged technologies employed in food processing and preservation. The antinutrient properties of foods are condensed via fermentation and thus, described as a pleasant biochemical change of food products initiated by microorganisms and their enzymes (Muchoki *et al.*, 2010; Nkhata *et al.*, 2018). Extrusion cooking technology is a process that involves the combination of heat and mechanical procedure while passing the raw food samples through compression screws and is pushed through a die or other restrictions (Iwe, 2003).

Plantain (*Musa paradisiaca)* is a giant perennial crop, cultivated in many tropics and subtropical countries of the world (Akomolafe and Aborisade 2007). Plantains are staple food that provides 60 million people with 25% calories (FAO, 2005). Plantain is used as a source of starchy staple food for millions of people in Nigeria (Akinyemi *et al.*, 2010). Mature plantain pulp is rich in iron, potassium and vitamin A but low in protein and fat (Adeniji *et al.*, 2006). Unripe plantain meal is usually consumed by diabetics to reduce postprandial glucose level (Onuoha et al., 2019). This is because the propensity of individual to develop diabetes and obesity is due to the increased consumption of carbohydrate-rich foods with a high glycemic index (Oboh and Erema, 2010).

Pigeon peas are leguminous shrubby herb, with trifoliate leaves, yellow flowers and flattened pods that is much cultivated especially in the tropics (Damaris, 2007). Pigeon pea is well adapted to the tropical environment (Mligo and Craufurd, 2005). One of the best solutions to protein energy malnutrition in developing countries is supplementing cereals with protein rich legumes

(Temba *et al.,* 2016). Pigeon pea flour has been tested and found to be suitable as a protein source for supplementing cereal food products due to its high level of protein, iron and phosphorus (Harinder *et al*., 1999).

The problem of malnutrition is predominant in Nigeria due to deficiency of protein and calories and protein-calories base vegetable have been recommended as a solution to this delinquent (Anuonye, 2012). The main objective of this study is to evaluate the fermentation and extrusion effects on the proximate and organoleptic components of unripe plantain and pigeon pea flour blends for human consumption.

2. MATERIALS AND METHODS

2.1 Collection of Samples

The samples i.e the healthy matured unripe plantain and the pigeon pea seeds were obtained from Oja Oba, Akure, Ondo state, Nigeria.

2.2 Processing of Samples

The protocol of *Ojokoh and Fagbemi* (2016) with some modification was deployed. Healthy matured unripe plantain was cleaned by washing with water. The clean plantains were peeled and sliced thinly into 2 mm diameter and sun dried for 72 hours. The dried unripe plantain was then fed into a Bentall attrition mill (Model 200L090). The milled flour was sieved with 0.25 mm mesh sieve into fine flour and kept in an air tight container.

Pigeon pea seeds were cleaned by sorting out dirt and stones. The cleaned pigeon pea seeds were coarsely milled to separate the coat from the cotyledon. The husk was separated from the seed by blowing air into it. The dehulled pigeon pea seeds were milled into fine flour using an attrition mill after which it was sieved through 0.25 mm mesh. The pigeon pea flour was kept in an airtight container.

2.3 Formation of pigeon pea-plantain Blends

The samples were formulated in the ratio of (unripe plantain: pigeon pea) 100:0; 70:30; and 50:50.

Sample A (100:0) = 100% unripe plantain flour

Sample B (70:30) = 70% unripe plantain flour and 30% pigeon pea flour

Sample C (50:50) = 50% unripe plantain flour and 50% pigeon pea flour

2.4 Fermentation and Extrusion of Flour Blends

The procedure of Ojokoh and Fagbemi (2016) was carried out with some adjustment. A group of the flour blend was fermented using semi- solid state fermentation for 96 hours. 70 ml of sterilized water was added to 100 g of each sample in cleaned containers and properly sealed. The fermentation process was terminated by oven drying at 60°C for 24 hours. Two batches of samples were subjected to extrusion cooking. The first batch consists of the unfermented blends. The blends were hydrated and preconditioned by adding 50 ml of water to 1000 g of the sample and manually mixed in a sterile bowl to ensure even distribution of water. The samples were extruded using a Brabender 20DN single screw laboratory extruder (Brabender OHG, Duisburg, Germany). The second batch of the samples consists of the fermented samples. The fermented samples were also extruded using a Brabender 20DN single screw laboratory extruder (BrabenderOHG, Duisburg, Germany). The samples were extruded at 100°C, 20 revolution per minute and feeding rate of 30 kg/h. All the extrudates were air dried for 12 hours after which they were stored at 32°C in sterile polyethylene bags and kept in properly labeled air tight containers. The control which consists of the raw blends which were neither fermented nor extruded was kept in air tight containers.

2.5 Microbiological Analysis of the Samples

Bacteria and fungi were evaluated using nutrient agar (NA) and potato dextrose agar (PDA) respectively while De Man Rogosa sharpe agar was used to isolate lactic acid bacteria. Techniques were enumerated by using appropriate serial dilution and pour plate techniques. The bacterial culture was incubated at 37°C for 18 to 24 hours, fungal plates were inverted and incubated at 24°C for 48 to 72 hours. De Man Rogosa sharpe agar plates were incubated at 32°C for 18 to 24 hours anaerobically. The organisms were characterized based on biochemical and morphological observations according to the methods of Fawole and Oso (2007) and (Cheesbrough, 2006).

2.6 Determination of pH and TTA

The pH of all fermenting samples was determined at 24 hours interval using a pocket size pH meter. A 1 g of the sample was dissolved in 10 ml of distilled water and filtered. The pH meter was calibrated with buffer solutions of pH 4, 7 and 9, this was followed by dipping the electrode of the pH meter into the sample solution and the observed pH was read and recorded in triplicates. The total titratable acidity of the fermenting samples was determined at 24 hours interval. A 2 g of macerated sample was weighed into a beaker. 20 ml of distilled water was added to it, it was mixed and filtered. 10 ml of the filtrate was measured into a beaker and 2 drops of phenolphthalein indicator was added into it. This was titrated with 0.1 M sodium hydroxide (NaOH) solution and the titre value was read. Total titratable acidity was expressed as percent (%) lactic acid. The acidity was calculated as: TTA= Titre value × 9 mg/100. The pH and TTA of the samples were carried out according to the method described by AOAC (2012).

2.7 Proximate Composition

All samples were analyzed for Moisture, Ash, Fat, Protein, Crude fiber and Carbohydrate determined by difference according to the method described by AOAC (2012).

2.8 Sensory Evaluation

The sensory evaluation was done by the method of panel of 15 judges (Larmond, 1977), samples of the raw flour blend, extruded unfermented (EUF), fermented extruded (FE) flour blend and fermented unextruded flour blend (FUE), and were served to the panel. The panels rated the samples based on the colour, aroma, texture, taste and overall acceptability by grading them on a seven-point hedonic scale (Lawless and Heymann, 2010)

2.9 Statistical Analysis

Statistical analyses of the Data were obtained using SPSS statistical software (SPSS for window version 20). Data obtained as mean standard deviations were analyzed by Analysis of Variance (ANOVA), followed by Duncan's New Multiple Range Test($P<0.05$) to determine the significant differences between the mean values.

3. RESULTS

3.1 Microorganisms Isolated during fermentation of samples

A total number of fifteen (15) microorganisms comprising nine (9) bacteria, two (2) yeasts and four (4) molds were isolated and identified as; *Bacillus subtilis*, *Bacillus cereus*, *Micrococcus luteus*, *Staphylococcus aureus*, *Lactobacillus plantarum*, *Lactobacillus fermentum*, *Leuconostoc mesenteroides*, *Lactobacillus mali*, *Streptococcus lactis*, *Saccharomyces cerevisiae*, *Candida utilis*, *Aspergillus niger*, *Aspergillus fumigatus*, *Aspergillus candidus*, and *Mucor hiemalis.*

3.2 pH of unripe plantain and pigeon pea flour blends during fermentation.

The pH variations during the fermentation of unripe plantain and pigeon pea blends are shown in Figure 1. Sample A gradually decreased from 5.80±0.00 to 5.10±0.03, Sample B decreased from 6.0±0.00 to 5.30±0.00, and sample C, decreased from 5.90±0.00 to 5.20±0.00.

3. Total titratable acidity of unripe plantain and pigeon pea flour blends during fermentation.

Variations in titratable acidity (TTA) during fermentation of unripe plantain and pigeon pea blends are represented in Figure 2. Sample A had TTA of 1.20±0.00 at 0 hour; this increased to 2.20±0.00 and 4.40±0.00 at 24 hours and 48 hours and increased slightly to 4.5±0.00 at 72 hours and finally decreased to 3.70±0.00 at 96 hours. Sample B increased from 1.00±0.00 at 0 hour and increased to 2.20±0.00 at 24 hours, decreased slightly to 2.00±0.00 at 48 hours and increased to 6.60±0.00 at 72 hours and finally decreased to 3.6±0.00 at 96 hours. Sample C at 0 hour increased from 1.10±0.00 to 2.30±0.00 at 24 hours and increased to 3.60±0.00 at 48 hours, decreased to 2.60±0.00 at 72 hours and finally decreased to 3.6±0.00 at 96 hours.

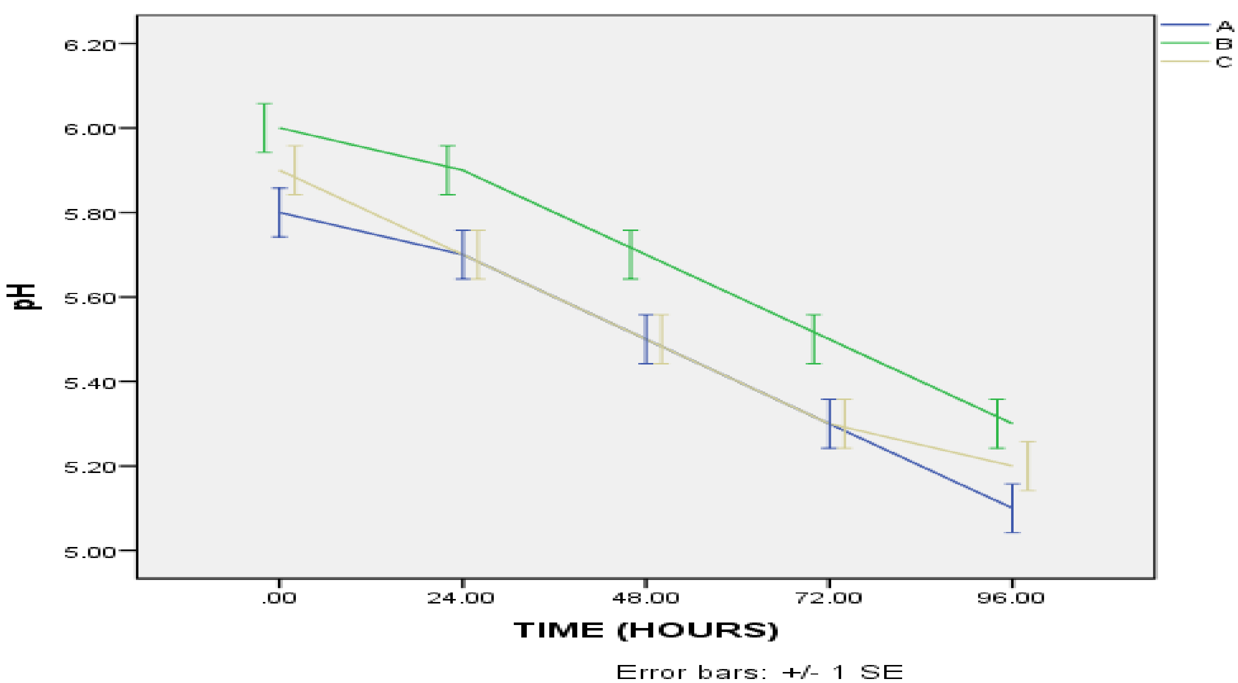

Figure 1: pH variation during fermentation of Unripe plantain and pigeon pea blends

KEYS*:*

A= 100g Unripe Plantain flour; B= 70g unripe plantain flour and 30g pigeon pea flour; C= 50g unripe plantain flour and 50g pigeon pea flour

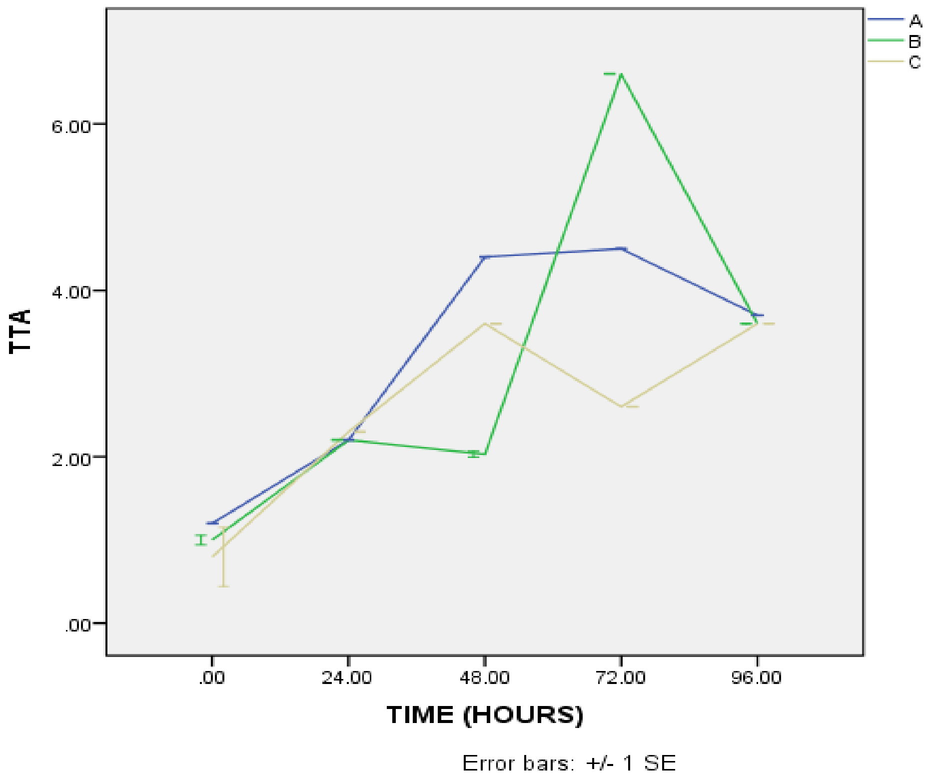

Figure 2: Total titratable acidity variation during fermentation of unripe plantain and pigeon pea blends

KEYS:

A= 100g Unripe Plantain flour; B= 70g unripe plantain flour and 30g pigeon pea flour; C= 50g unripe plantain flour and 50g pigeon pea flour

3.4 Proximate composition of unripe plantain and pigeon pea flour blend.

The moisture content of unripe plantain and pigeon pea flour blends are represented in Table 1. Raw flour blend had the lowest moisture content with values ranging from 5.63±0.01 to 6.69±0.00. There was significant difference (p≤0.05) in raw flour A and B. Fermented samples had the highest moisture content ranging from 11.23±0.00 to 11.73±0.01 in samples A to C. The extruded unfermented blends ranged from 8.77±0.00 to 9.53±0.01 in samples A to C. Fermented-extruded samples exhibited moisture content ranging from 8.33±0.00 to 10.64±0.00.

The changes in the ash content of unripe plantain and pigeon pea flour blends are represented in Table 1. The ash content of the raw blends range from 1.39±0.00 to 3.22±0.00. There is a significant difference between samples B and C. Fermented samples had values ranging from 2.11±0.00 to 2.78±0.01. Extruded unfermented samples had values ranging from 2.63±0.00 to 2.83±0.00. Extruded fermented blends had ash content ranging from 2.25±0.00 to 2.28±0.03.

The variations in protein content of unripe plantain and pigeon pea flour blends are shown in Table 1. There was significant (p≤0.05) difference in the raw flour blends with values ranging from 2.57±0.35 to 10.17±0.18. Fermented samples recorded significant difference (p≤0.05) for all the blends with values ranging from 3.66±0.08 to 13.41±0.69. The extruded unfermented exhibited protein content ranging from 2.86±0.88 to 12.03±0.53. Extruded fermented samples exhibited significant difference (p≤0.05) among all the blends with values ranging from 2.58±0.37 to 16.27±0.43.

The crude fibre content of the unripe plantain and pigeon pea flour blends are shown in Table 1. There was significant difference (p≤0.05) in the crude fibre content of the blends. The crude fibre of the raw blends range from 5.07±0.03 to 7.44±0.35. Fermented blends had the highest crude fibre content ranging from 8.87±0.09 to 11.02±0.13. Extruded unfermented blends had crude fibre content ranging from 5.89±0.15 to 8.05±0.13. Extruded fermented blends ranged from 6.35±0.23 to 9.48±0.28.

The fat content of unripe plantain and pigeon pea flour blends are shown in Table 1. There was significant (p≤0.05) difference in the fat content of the raw flour blends A to C with values ranging from 1.33±0.03 to 2.01±0.03. The fermented samples had the highest fat content with values ranging from 2.52±0.01 to 6.33±0.03. There were significant (p≤0.05) differences in the extruded unfermented blends A to C with values 2.38±0.05 to 5.37±0.06. Fat content of extruded fermented samples ranged from 2.29±0.06 to 4.25±0.03.

The carbohydrate content of unripe plantain and pigeon pea flour blends are shown in Table 1. Carbohydrate content of raw flour blends ranged from 67.97±0.29 to 74.32±0.38. The fermented blends had carbohydrate content ranging from 38.28±0.47 to 62.72±0.29. Extruded unfermented blends had carbohydrate content ranging from 63.18±0.34 to 71.04±0.68. The extruded fermented blends had values ranging from 60.03±0.48 to 73.47±0.62.

Table 1. Proximate composition unripe plantain and pigeon pea blend (%)

SAMPLE	MOISTURE (%)	ASH (%)	PROTEIN (%)	CRUDE FIBRE (%)	FAT (%)	CARBOHYDRATE (%)
ARF	5.63±0.01^{a}	3.22±0.00^{d}	2.57±0.03^{a}	5.07±0.01^{a}	1.33±0.02^{a}	74.32±0.00^{g}
BRF	6.34±0.00^{b}	3.13±0.00^{d}	6.43±0.00^{c}	7.23±0.01^{c}	1.75±0.01^{ab}	70.06±0.00^{f}
CRF	6.69±0.00^{b}	1.39±0.00^{a}	10.17±0.00^{c}	7.44±0.00^{c}	2.01±0.02^{b}	67.97±0.02^{f}
AFU	11.73±0.01^{f}	2.11±0.00^{b}	3.66±0.03^{b}	8.87±0.00^{d}	2.52±0.01^{c}	62.72±0.01^{d}
BFU	11.48±0.03^{f}	2.32±0.03^{b}	7.52±0.01^{d}	9.17±0.02^{de}	5.85±0.00^{e}	54.43±0.02^{b}
CFU	11.23±0.00^{f}	2.78±0.01^{bc}	13.41±0.03^{f}	11.02±0.02^{f}	6.33±0.00^{f}	38.28±0.01^{a}
AUE	9.44±0.01^{d}	2.83±0.00^{c}	2.86±0.00^{a}	5.89±0.00^{ab}	2.38±0.00^{b}	71.04±0.02^{g}
BUE	9.53±0.01^{d}	3.39±0.00^{d}	6.80±0.01^{cd}	7.61±0.01^{c}	4.29±0.00^{d}	63.18±0.01^{d}
CUE	8.77±0.00^{c}	2.63±0.00^{bc}	12.03±0.00^{e}	8.05±0.03^{d}	5.37±0.00^{e}	65.82±0.03^{de}
AFE	10.64±0.00^{e}	2.28±0.03^{b}	2.58±0.02^{a}	6.35±0.00^{b}	2.29±0.01^{b}	73.47±0.00^{g}
BFE	8.33±0.00^{c}	2.25±0.00^{b}	13.10±0.00^{f}	8.21±0.00^{d}	2.98±0.02^{c}	64.80±0.02^{d}
CFE	9.53±0.01^{d}	2.32±0.00^{b}	16.27±0.01^{g}	9.48±0.00^{e}	4.25±0.03^{d}	60.03±0.00^{c}

Values are means of triplicate determinations ± SD. Means in the same column with different superscripts are significantly different (p≤0.05)

Keys: ARF= Raw unripe plantain flour 100g; BRF= Raw unripe plantain flour 70g and raw pigeon pea flour 30g; CRF= Raw unripe plantain flour 50g and raw pigeon pea flour 50g; AFU= Fermented unextruded unripe plantain flour 100g; BFU= Fermented unextruded unripe plantain flour 70g and pigeon pea 30g; CFU= Fermented unextruded unripe plantain flour 50g and pigeon pea 50g; AUE= Unfermented extruded unripe plantain flour 100g; BUE= Unfermented extruded unripe plantain flour 70g and pigeon pea 30g; CUE= Unfermented extruded unripe plantain flour 50g and pigeon pea 50g;

AFE= Fermented extruded unripe plantain flour 100g; BFE= Fermented extruded unripe plantain flour 70g and pigeon pea 30g; CFE= Fermented extruded unripe plantain flour 50g and pigeon pea 50g

3.4.7 Sensory Evaluation of unripe plantain and pigeon pea blends

The result obtained in the evaluation demonstrated that there was no significant difference in the blends for colour, texture, aroma, taste and overall acceptability. Fermented blends and extruded-fermented blend recorded low values for colour. Raw blends, fermented blends and extruded-unfermented blends recorded highest values for texture. Fermented-extruded blends had the highest value for taste. Fermented-extruded blends recorded highest value for aroma. Raw blends, unfermented-extruded blends and extruded-fermented had the highest values for overall acceptability. This result is represented in Table 2.

Table 2: Sensory Evaluation of Unripe Plantain and Pigeon pea Blends

SAMPLE	COLOUR	TEXTURE	AROMA	TASTE	OVERALL ACCEPTABILITY
ARF	6.20 ± 0.01^{f}	6.20 ± 0.00^{cd}	5.20 ± 0.00^{b}	6.00 ± 0.00^{c}	6.50 ± 0.00^{c}
BRF	6.00 ± 0.00^{f}	5.70 ± 0.00^{c}	4.50 ± 0.01^{a}	5.30 ± 0.00^{b}	5.80 ± 0.00^{bc}
CRF	5.40 ± 0.00^{e}	5.80 ± 0.00^{c}	4.00 ± 0.00^{a}	6.10 ± 0.00^{c}	6.30 ± 0.01^{c}
AFU	4.50 ± 0.00^{d}	5.20 ± 0.00^{bc}	6.10 ± 0.00^{c}	6.20 ± 0.01^{c}	5.30 ± 0.01^{b}
BFU	3.20 ± 0.00^{b}	4.50 ± 0.01^{ab}	5.20 ± 0.00^{b}	5.60 ± 0.00^{b}	4.70 ± 0.00^{a}
CFU	2.50 ± 0.00^{a}	5.00 ± 0.00^{b}	5.70 ± 0.00^{bc}	5.80 ± 0.00^{bc}	5.10 ± 0.00^{b}
AUE	6.00 ± 0.01^{f}	5.50 ± 0.00^{c}	5.30 ± 0.01^{b}	5.00 ± 0.00^{b}	5.60 ± 0.00^{b}
BUE	4.70 ± 0.00^{d}	5.20 ± 0.00^{bc}	5.10 ± 0.00^{b}	6.20 ± 0.00^{c}	5.30 ± 0.01^{b}
CUE	5.60 ± 0.00^{e}	5.00 ± 0.00^{b}	5.00 ± 0.00^{b}	4.20 ± 0.01^{a}	4.50 ± 0.00^{a}
AFE	4.80 ± 0.00^{d}	4.20 ± 0.00^{a}	6.40 ± 0.00^{c}	6.30 ± 0.00^{c}	5.50 ± 0.00^{b}
BFE	5.50 ± 0.01^{e}	4.70 ± 0.00^{b}	6.20 ± 0.00^{c}	5.10 ± 0.00^{b}	5.70 ± 0.00^{bc}
CFE	4.00 ± 0.00^{c}	5.50 ± 0.00^{c}	6.10 ± 0.01^{c}	6.10 ± 0.00^{c}	6.10 ± 0.01^{c}

Values are means of triplicate determinations ± SD. Means in the same column with different superscripts are significantly different ($p \leq 0.05$)

Keys: ARF= Raw unripe plantain flour 100g; BRF= Raw unripe plantain flour 70g and raw pigeon pea flour 30g; CRF= Raw unripe plantain flour 50g and raw pigeon pea flour 50g; AFU= Fermented unextruded unripe plantain flour 100g; BFU= Fermented unextruded unripe plantain flour 70g and pigeon pea 30g; CFU= Fermented unextruded unripe plantain flour 50g and pigeon pea 50g; AUE= Unfermented extruded unripe plantain flour 100g; BUE= Unfermented extruded unripe plantain flour 70g and pigeon pea 30g; CUE= Unfermented extruded unripe plantain flour 50g and pigeon pea 50g; AFE= Fermented extruded unripe plantain flour 100g; BFE= Fermented extruded unripe plantain flour 70g and pigeon pea 30g; CFE= Fermented extruded unripe plantain flour 50g and pigeon pea 50g

4. DISCUSSION

The identified microorganisms in the fermenting media were similar to the findings of Ojokoh and Udeh (2014) that legume supplemented products had a greater microbial diversity and higher microbial populations.

As fermentation progressed, the pH of the samples decreased. The lowering of pH may be as a result of the activities of microorganisms on the fermentable medium which led to the hydrolysis of complex organic compounds of the medium thereby resulting into the production of acid and ethanol. The acids produced brought about a decrease in pH and increase in total titratable acidity which consequently resulted in low microbial load (Hassan *et al.,* 2015). Related results were reported by Hassan *et al.,* (2015) and Ojokoh and Udeh (2014). However, the result of this research suggests that it is a lactic type where pH of fermenting media decreases with increase in total titratable acidity (TTA).

Increase in moisture content of fermented and extruded blends may be due to hydration. Moderate increase in the moisture content of unfermented extruded, fermented unextruded and fermented extruded blends may cause reduction in cooking time and fuel consumption. Similar result was also reported by Oladunmoye (2007) during fermentation of locust beans.

The protein increased with increasing level of pigeon pea flour substitution indicating nutrient enhancement. This could obviously be due to the significant quantity of protein in pigeon pea seeds. The increase in protein content is similar to some other research study in which cowpea flour was used in supplementation, such as in ogi supplemented with cowpea (Ashaye *et al.,* 2001). Increase in the protein content of fermented unextruded blends could be as a result of protein synthesis by microorganisms during fermentation which contribute to high value in fermented samples. This increase could be attributed to the increase in microbial load during fermentation, causing extensive hydrolysis of the protein molecule to amino acid and other simple peptides (Igbabul *et al.,* 2014).

The carbohydrate content of the raw blends decreased with increase in pigeon pea, this agrees with the report of Abiodun and Ogugua (2012). Reduction in the carbohydrate content of fermented unextruded blends could be as a result of utilization of carbohydrate by microorganisms during fermentation. Decrease in carbohydrate content of fermented samples may be because it was used up as the main source of energy during fermentation. This may be because fermentation improved carbohydrate content of the blend (Anuonye *et al*., 2009).

Fat (including oil) are one of the major components of food that provides essential lipids and energy. Lipid constituent is the major determinants of overall physical characteristics of food such as aroma and texture. Fat content was highest in fermented unextruded blends. This could be as a result of the metabolic activities of the fermenting microorganisms. Reduction in the fat content of unfermented extruded and fermented extruded blends could be due to lipid oxidation. Lipid oxidation can reduce the nutritive quality of food by decreasing the content of essential fatty acids, such as linoleic and linolenic acid, which are essential fatty acids. These long chained fatty acids are highly susceptible to oxidation which results from application of temperature during extrusion. (Ranjit and Subha, 2014).

Fermented unextruded blends had the highest crude fibre content but unfermented extruded and fermented extruded blends had low crude fibre content. This implies that extrusion had negative impact on the crude fibre content of the blends which compares favourably with the work of Eze and Ibe (2005) on the effect of fermentation on the nutritive value of *B. eurycoma* "Achi" where an increase in fibre content for the fermented samples may be due to the activities of microorganisms.

Fermentation caused a significant reduction in the ash content of the samples. Michodjehoun *et al.* (2005) also reported a decrease in ash content during fermentation of " Gowe", a traditional food made from sorghum, millet or maize.

The result obtained in the sensory evaluation indicated that there was no significant difference in the colour of the raw flour blends and unfermented extruded blends. Fermented unextruded blends and fermented extruded blends recorded significantly low values for colour. There was no significant difference in the texture of raw blends and unfermented extruded blends. Fermented blends recorded significantly high values in terms of aroma. Raw blends and fermented blends recorded high values for overall acceptability. This result is represented in table 2. The fermented blends had better flavour than other test blends while raw blends had the highest colour. Based on these, they were much more acceptable. This is not surprising because it is known that appearance of food evokes the initial response and flavour determines the final acceptance or rejection of the product by the consumer (Onoja and Obizoba, 2009).

5. CONCLUSION

The investigation so far revealed that the blending of unripe plantain and pigeon pea has the potential of producing enriched complementary food for improving the health of malnourished children of developing countries. From the results of this research, it is evident that fermentation and extrusion will produce acceptable products and will go a long way to increase the nutritional and sensory attributes of blends.

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