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Proximate composition, antinutritional contents and physicochemical properties of breadfruit (*Treculia africana*) and cowpea (*Vigna unguiculata*) flour blends fermented with *Lactobacillus plantarum*

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This study investigates proximate composition, antinutritional contents and physicochemical properties of breadfruit (*Treculia africana*) and cowpea (*Vigna unguiculata*) flour blends fermented with pure strains *Lactobacillus plantarum* (FO-12) for the purpose of developing weaning food for the management of protein-energy malnutrition (PEM). Breadfruit and cowpea flour blends were prepared in various ratios and then fermented using *Lactobacillus plantarum.* Proximate composition, phytic acid, hydrogen cyanide and oxalate contents were determined. pH and titratable acidity were also determined. A significant increase ($p < 0.05$) was observed in the ash, protein and fat contents of the fermented flour blend as the amount of cowpea flour increases in the formulation; whereas crude fibre and carbohydrate contents significantly decreased ($p < 0.05$). Similarly, moisture, protein and fat contents significantly increased ($p < 0.05$) with fermentation. Significant reductions were observed in crude fibre and carbohydrate contents after fermentation. Fermentation process caused a significant decrease ($p < 0.05$) in the oxalate, phytate and hydrogen cyanide contents of the breadfruit flour blends. The changes observed in the fermented flour blends agreed with significant decreases recorded for pH and increases in titratable acidity. Fermentation improves the nutritional composition of breadfruit-cowpea flour blends for possible use as complementary foods for infants providing PEM management.

Key words: Breadfruit-cowpea flour blends, fermentation, *Lactobacillus plantarum,* weaning food, physico-chemical properties.

INTRODUCTION

African breadfruit (*Treculia africana*) from the mulberry family *Moraceace* is an important food crop in Nigeria (Ejiofor et al., 1988). It is widely cultivated in the southern states of Nigeria (Badifu and Ubor, 2001; Ugwu et al., 2001) and generally regarded as the poor man's substitute for yam (*Dioscorea esculenta* and *Dioscorea*

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cayenensis). This is due to the fact that it is used in several traditional food preparations of yam, and also cost less than one third the price of yam at the market (Mayaki et al., 2003). Breadfruit contains about 1.34% protein, 0.31% fat, 27.82% carbohydrate, 1.5% fibre and 1.23% ash (Wang et al., 2011). It is also rich in calcium, phosphorus, iron, potassium, carotene and vitamin B (Wang et al., 2011). Breadfruit powder or flour is reported to contain about 76.7% carbohydrate (Morton, 1987), 17.1% protein, 11% fat, 3.0% ash and 0.1% crude fiber (Akubor et al., 2000).

The presence of anti-nutritional factors limits the use of this crop. However, they could be eliminated or reduced by some processes such as soaking, dehulling, germination and fermentation (Khokhar and Chauhan, 1986). The study of Onweluzo and Nnamuchi (2009) reveals that fermentation and steaming enhances the detoxification of breadfruit flour. But fermentation as a method of processing and preserving breadfruit, as obtains in the Pacific Islands, is quite unpopular in most areas where it has been introduced (Adekanmi et al., 2012). Protein-energy malnutrition (PEM) has resulted in high level of infants and children mortality in Nigeria, especially among the low income earners. Cowpea is an important food legume indigenous to Africa (Khalid et al., 2012). It provides more than half the plant protein in human diets (Rachie, 1985). Cowpea has been reported to contain about 20.07 to 24.60% protein, 46.84 to 53.63 starch (carbohydrate), 1.77 to 1.96% fat and 4.27 to 4.96% fibre (Preet and Punia, 2000), as well as 3.50% ash (Darfour et al., 2012). The black-eyed cowpea (*Vigna unguiculata*) used for this research is an important food legume in Nigeria.

Composite meals have been developed from African breadfruit and tubers such as sweet potatoes, yam and cocoyam (Akubor, 1997; Oladeji and Akanbi, 2011) and cereals like sorghum (Onweluzo and Nnamuchi, 2009) but enrichment of breadfruit with cowpea which has the potential of alleviating protein-energy malnutrition among children in Nigeria has not received considerable attention. Due to the high dependence on breadfruit as a staple food in tropical Africa, coupled with the low nutritive value of the commodity, it is imperative to investigate simple processing method that can improve the nutrition qualities of the crop.

Although, fermentation improves the nutritive value of cowpea, but the process is not popular in Nigeria. Fermentation of breadfruit with cowpea could be a useful process of improving the health of vast numbers of infants and children at low cost especially in the rural areas. This might offer a significantly cheap and sustainable food process that will reduce micronutrient deficiency. Our previous study has been on the effect of spontaneous fermentation on nutrient and anti-nutrient composition of breadfruit and cowpea blend flours. In this study, the proximate, antinutritional and physicochemical properties of African breadfruit and cowpea flour blends that are fermented with pure strain of *Lactobacillus plantarum* (FO-12) isolated from spontaneous fermentation of breadfruit were investigated.

MATERIALS AND METHODS

Source of raw materials

Freshly harvested, matured but un-riped breadfruit (*Treculia africana*) and dried cowpea (*Vigna unguiculata*) were purchased from a local market in Ibadan, south-west area of Nigeria. These raw materials were packaged in low density polyethylene bag and then transported to the Laboratory for processing and analyses.

Preparation of breadfruit flour

Breadfruits were washed, manually peeled and diced into sizes. The diced fruits were blanched in boiling water (100°C) for 10 min., dried in air-oven at 65°C for 24 h., milled using Hammer Mill (Brook Crompton, Huddersfield, England) and then sieved through 600 µm aperture size to obtain fine flour (Figure 1).

Preparation of cowpea flour

About 100 g of cowpea was sorted and cleaned to remove extraneous materials and defective seeds. The seeds were soaked in distilled water for 25 min and then dehulled using mortar and pestle. The dehulled seeds were washed, dried at 65°C for 24 h in air-oven, milled and then sieved through 600 µm aperture size to obtain fine flour (Figure 1).

Preparation of breadfruit-cowpea flour blends (composites)

Breadfruit-cowpea flour blends were composited in the ratios 100:0 breadfruit flour to cowpea flour blend (TvA), 90:10 breadfruit flour to cowpea flour blend (TvB), 80:20 breadfruit flour to cowpea flour blend (TvC), 70:30 breadfruit flour to cowpea flour blend (TvD), 60:40 breadfruit flour to cowpea flour blend (TvE) and 50:50 breadfruit flour to cowpea flour blend (TvF) (Ojokoh et al., 2013) as outlined in Figure 1.

Fermentation process

Bacterial strains used for fermentation

The strain of *Lactobacillus plantarum* (*L. plantarum,* FO-12) used for the fermentation was isolated from previous study on spontaneous fermentation of breadfruit (Ojokoh et al., 2013). The strain was selected after morphological, phenotypic and molecular characterisation as described by Sawitzki et al. (2007). The isolated strain was preserved in microbial vials.

Fermentation of the breadfruit-cowpea flour blends

The *L. plantarium* (FO-12) was first grown in MRS broth (Merck, Darmstadt, Germany) for 18 h at 37°C after which it centrifuged (at 240 rpm for 10 min), re-washed with sterile distilled water and standardized (Using MacCfarland standard). The inoculum was then added to the composite flour which was re-constituted in sterile distilled water in a transparent sterile container. The samples were left to ferment for 72 h. Daily (24 h) changes in pH and

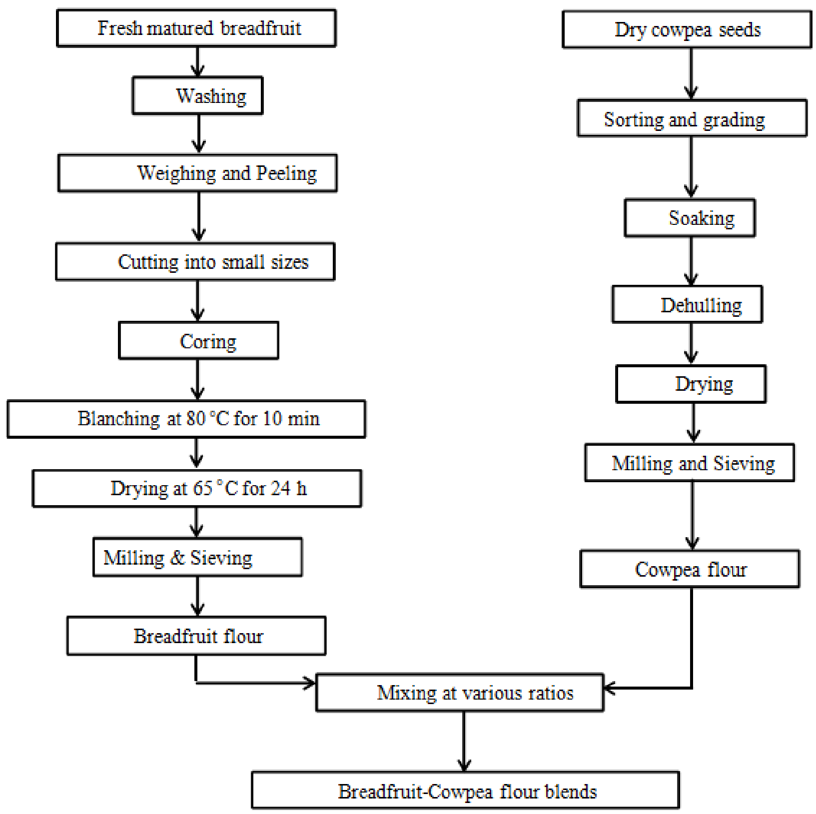

Figure 1. Flow chart for the preparation of breadfruit-cowpea flour blends (Composites).

titratable acidity were determined. At the end of fermentation, the fermented samples were dried in air-oven and packaged in low density polyethylene pouches and stored at 8 °C prior to analyses. The fermentation process was carried out in three batches.

Physico-chemical properties

pH and titratable acidity

The method described by AOAC (1998) was used to determine pH and titratable acidity of the fermenting medium. Samples were taken every 24 h during the fermentation period and homogenised according to the procedure described by Fayemi and Ojokoh (2012). Samples were measured using an Orion pH meter (Model 310, Orion Research Inc., Beverly, MA) equipped with glass electrode. The pH meter was calibrated with KOH buffer solutions of pH 7.0 and 4.0 before the measurements. The titratable acidity (TTA) was determined by titrating 20 ml of the homogenised sample against 0.1 M NaOH using phenolphthalein as an indicator. Values obtained were expressed as percent lactic acid. All analyses were carried out in triplicate.

Proximate composition

The moisture, crude protein (N × 6.25), crude fibre, crude fat and total ash contents of breadfruit-cowpea flour blends (composites) were determined before and after 72 h of fermentation using the method described by Association of Official Analytical Chemists' (AOAC, 1998) approved methods 925.10, 920.87, 920.86, 920.39 and 923.03 respectively. Total carbohydrate content of the samples was calculated by difference method (subtracting the percent moisture, crude protein, crude fibre, crude fat, and ash from 100%)

Antinutritional contents

Phytate and hydrogen cyanide (HCN) contents were determined by AOAC (1998) method. Oxalate content was measured according to the titrimetric method (AOAC, 1998).

Statistical analysis

All measurements were carried out in triplicate. Analysis of variance (ANOVA) was conducted on the data at $p < 0.05$ using MINITAB statistical software (Minitab® Release 14.13, Minitab Inc., USA). The least significant difference (LSD) at 95% confidence level was computed to ascertain where differences exist.

RESULTS AND DISCUSSION

Proximate composition

The proximate composition of fermented and unfer-mented breadfruit-cowpea flour blends is shown in

Table 1. Proximate composition of fermented and unfermented breadfruit-cowpea flour blends.

Proximate (%)	TvA		TvB		TvC		TvD		TvE		TvF	
	Unfermented	Fermented	Unfermented	Fermented	Unfermented	Fermented	Unfermented	Fermented	Unfermented	Fermented	Unfermented	Fermented
Moisture	$9.30^{b} \pm 0.26$	$10.93^{c} \pm 0.07$	$9.17^{a} \pm 0.04$	$10.91^{c} \pm 0.02$	$9.13^{a} \pm 0.02$	$10.95^{c} \pm 0.03$	$9.14^{a} \pm 0.02$	$10.93^{c} \pm 0.03$	$9.16^{a} \pm 0.02$	$10.92^{c} \pm 0.02$	$9.03^{a} \pm 0.02$	$10.77^{bc} \pm 0.02$
Total ash	$2.40^{a} \pm 0.03$	$2.42^{a} \pm 0.03$	$2.63^{b} \pm 0.03$	$2.61^{b} \pm 0.02$	$2.85^{c} \pm 0.02$	$2.87^{c} \pm 0.02$	$3.08^{d} \pm 0.02$	$3.11^{d} \pm 0.03$	$3.30^{e} \pm 0.02$	$3.35^{f} \pm 0.03$	$3.56^{g} \pm 0.02$	$3.61^{h} \pm 0.02$
Crude fibre	$3.25^{h} \pm 0.02$	$2.88^{f} \pm 0.02$	$2.94^{g} \pm 0.03$	$2.68^{e} \pm 0.03$	$2.69^{e} \pm 0.02$	$2.45^{d} \pm 0.03$	$2.47^{d} \pm 0.02$	$2.24^{c} \pm 0.02$	$2.26^{c} \pm 0.03$	$2.88^{f} \pm 0.02$	$2.06^{b} \pm 0.02$	$1.83^{a} \pm 0.03$
Crude protein	$4.00^{a} \pm 0.20$	$7.25^{c} \pm 0.15$	$5.86^{b} \pm 0.04$	$11.23^{f} \pm 0.16$	$7.87^{d} \pm 0.02$	$13.35^{h} \pm 1.15$	$9.93^{e} \pm 0.04$	$15.21^{j} \pm 0.03$	$11.91^{g} \pm 0.05$	$17.24^{k} \pm 0.02$	$14.18^{i} \pm 0.06$	$24.14^{l} \pm 0.02$
Fat	$2.27^{a} \pm 0.25$	$3.59^{g} \pm 0.07$	$2.55^{b} \pm 0.04$	$3.74^{h} \pm 0.02$	$2.71^{c} \pm 0.02$	$3.05^{d} \pm 0.03$	$2.92^{d} \pm 0.02$	$4.18^{i} \pm 0.03$	$3.13^{e} \pm 0.03$	$4.36^{j} \pm 0.02$	$3.34^{f} \pm 0.02$	$4.72^{k} \pm 0.03$
Carbohydrate	$80.14^{g} \pm 1.43$	$73.58^{e} \pm 0.47$	$77.09^{f} \pm 0.11$	$68.77^{d} \pm 0.17$	$74.72^{e} \pm 0.03$	$66.66^{d} \pm 0.02$	$72.46^{e} \pm 0.04$	$64.41^{bc} \pm 0.04$	$70.20^{dc} \pm 0.02$	$63.18^{b} \pm 0.02$	$67.92^{d} \pm 0.02$	$55.13^{a} \pm 0.13$

Values are means ± standard deviation of triplicates. Values in the same row with different superscripts are significantly different at $p < 0.05$. TvA = 100:0 breadfruit flour to cowpea flour blend; TvB = 90:10 breadfruit flour to cowpea flour blend; TvC = 80:20 breadfruit flour to cowpea flour blend; TvD = 70:30 breadfruit flour to cowpea flour blend; TvE = 60:40 breadfruit flour to cowpea flour blend; TvF = 50:50 breadfruit flour to cowpea flour blend.

Table 1. Moisture content of the unfermented and fermented breadfruit-cowpea flour blends ranged from 9.03 - 9.30% and 10.77 - 10.95% respectively (Table 1). Apart from the unfermented breadfruit-cowpea flour blend (100:0) (TvA), the moisture contents for other flour blends were not significantly different ($p > 0.05$) from each other (Table 1). Besides, the moisture contents for the fermented breadfruit-cowpea flour blends were not significantly different ($p > 0.05$) from each other. However, moisture contents were significantly higher ($p < 0.05$) for all the fermented samples compared with unfermented samples (Table 1). This result is in agreement with our previous study, where the breadfruit-cowpea flour blends were subjected to spontaneous fermentation (Ojokoh et al., 2013). Ojokoh et al. (2013) reported mean moisture content values of 9.09 and 10.52% for all unfermented and fermented samples. Moisture content of 9.61% has been reported for breadfruit flour (Ajani et al., 2012). Ariahu et al. (1999) also reported moisture content values of 9.8 and 10.4% for nongerminated-nonfermented soy-breadfruit seed and nongerminated-fermented soy-breadfruit seed food formulations respectively. Moisture content of flour provides an indication of shelf stability of the flour. It is however, depended upon the temperature and duration of the drying process. The low moisture contents recorded for all the flour blends suggest good keeping quality of the samples.

The total ash contents for unfermented and fermented breadfruit-cowpea flour blends ranged from 2.40 - 3.56% and 2.42 - 3.61% respectively (Table 1). These values increased significantly ($p < 0.05$) as the amount of cowpea flour proportions in the breadfruit-cowpea flour blends increased for both unfermented and fermented samples. The total ash content values for the unfermented samples were not significantly different ($p > 0.05$) from fermented samples, except for 60:40 and 50:50 breadfruit-cowpea flour blend samples which significantly increased ($p < 0.05$) with fermentation (Table 1). The ash content values observed in this study were similar to the mean ash contents of 2.96 and 2.97% reported earlier for unfermented and fermented breadfruit-cowpea blend flours respectively (Ojokoh et al., 2013). Ash content of 1.05% has been reported for breadfruit flour (Ajani et al., 2012). Values of 2.14, 2.82 and 1.27% have been reported for parboiled, boiled and fermented African breadfruit flours respectively (Onweluzo and Nnamuchi, 2009). Also, values of 1.8 and 2.5% ash have been reported for nongerminated-nonfermented soy-breadfruit seed and nongerminated-fermented soy-breadfruit seed food formulations respectively (Ariahu et al., 1999). The increases in ash contents for both unfermented and fermented breadfruit-cowpea flour blends due to increase in cowpea flour proportion, could be attributed to the high ash content of cowpea. Ash content of 3.50% has been reported for cowpea flour (Darfour et al., 2012). Giami (1993) also reported ash content of 3.1% for cowpea flour. The results obtained from the measurements to determine ash content demonstrate that breadfruit-cowpea flour blends (fermented and unfermented) with 50:50 ratio(TvF) is richer in minerals when compared to the other formulations.

Crude fibre contents ranged from 2.06 - 3.25% for unfermented and 1.83 - 2.88% for fermented breadfruit- cowpea flour blends (Table 1). Increasing the proportions of cowpea significantly decreased ($p < 0.05$) the crude fibre contents of the breadfruit-cowpea flour blends. Similarly, fermentation caused a significant decrease ($p < 0.05$) in the crude fibre contents of the breadfruit-cowpea flour blends. Mean fibre contents of 2.60 and 2.46% for unfermented and fermented breadfruit-cowpea flour blends were stated in our previous study (Ojokoh et al., 2013). High fibre content values of 3.9 and 4.5% have also been reported for nongerminated-nonfermented soy-breadfruit seed and nongerminated-fermented soy-breadfruit seed food formulations respectively (Ariahu et al., 1999). Ajani et al. (2012) also reported fibre content of 1.26% for breadfruit flour. The decrease in crude fibre content of breadfruit-cowpea flour blends with increase in cowpea levels might be due to low content of fibre in cowpea. Giami (1993) reported crude fibre content of 2.1% for cowpea flour. Furthermore, the reduction in crude fibre content in the fermented breadfruit-cowpea flour blends could be attributed to enzymatic breakdown of fibre during fermentation by the *Lactobacillus plantarum* (Ojokoh et al., 2013). However, increased crude fibre content has been reported in fermented maize flour (Amankwah et al., 2009).

Crude protein contents ranged from 4.00 - 14.18 % for unfermented and 7.25 - 24.14% for fermented breadfruit-cowpea flour blends (Table 1). Increasing the proportions of cowpea significantly increased ($p < 0.05$) the crude protein contents of the breadfruit-cowpea flour blends. Also, crude protein significantly increased ($p < 0.05$) with fermentation of the breadfruit-cowpea flour blends (Table 1). This result compared favourably with our previous values, where mean protein content of 8.91 and 10.27% were recorded for unfermented and fermented breadfruit-cowpea blend flours respectively (Ojokoh et al., 2013). Ariahu et al. (1999) reported crude protein content of 16.4 and 16.8% for nongerminated-nonfermented soy-breadfruit seed and nongerminated-fermented soy-breadfruit seed food formulations respectively. However, protein content of 1.34% has also been reported for breadfruit flour (Ajani et al., 2012). Protein contents (dry weight basis) of 18.65, 24.18 and 20.78% have been reported for parboiled, boiled and fermented African breadfruit flours respectively (Onweluzo and Nnamuchi, 2009). Other researchers also reported similar or greater increases in crude protein of cowpea (Giami, 1993) and various fermented Nigerian legumes and oilseeds (Akpapunam and Achinewhu (1985). The increased crude protein content of breadfruit-cowpea flour blends observed with increasing cowpea levels could be attributed to the high content of protein in cowpea (Giami, 1993). Also, the increases in crude protein content recorded with fermentation could be due to the activities and increase in number of *Lactobacillus plantarum* (Ojokoh et al., 2013). Amankwah et al. (2009) reported increased protein content in fermented maize flour. This increase in protein content was attributed to proteolytic activities of enzymes produced by microorganisms during fermentation (Amankwah et al., 2009).

Fat contents of breadfruit-cowpea flour blends ranged from 2.27 - 3.34% and 3.59 - 4.72% for unfermented and fermented samples respectively (Table 1). Fat contents increased significantly ($p < 0.05$) with increasing cowpea proportions of the breadfruit-cowpea flour blends. Fermentation also, significantly increased ($p < 0.05$) the fat contents of the breadfruit-cowpea flour blends (Table 1). Mean fat contents of 2.82 and 3.28% were previously reported for unfermented and fermented breadfruit-cowpea blend flours respectively (Ojokoh et al., 2013). Fat content of 0.595% has also been reported for breadfruit flour (Ajani et al., 2012). Other researchers also reported increases in fat content (crude ether extract) for fermented African breadfruit flour (Onweluzo and Nnamuchi, 2009), fermented maize flour (Amankwah et al., 2009), fermented cowpea (Akpapunam and Achinewhu, 1985) and fermented fluted pumpkin seeds (Achinewhu and Isichei, 1990). The increased fat content of breadfruit-cowpea flour blends observed with increasing cowpea levels could be attributed to the high content of fat in cowpea. Also, the increases in fat content observed with fermentation could be due to the activities of lipolytic enzymes produced by *Lactobacillus plantarum* during fermentation (Onweluzo and Nnamuchi, 2009; Akpapunam and Achinewhu, 1985; Achinewhu and Isichei and Ojokoh et al., 2013).

Carbohydrate contents for unfermented and fermented breadfruit-cowpea flour blends ranged from 67.92 - 80.14% and 55.13 - 73.58% respectively (Table 1). These values decreased significantly ($p < 0.05$) with increase in cowpea flour proportion in the breadfruit-cowpea flour blends for both unfermented and fermented samples. Fermentation was also found to significantly decreased ($p < 0.05$) the carbohydrate contents of breadfruit-cowpea flour blends (Table 1). The carbohydrate content values observed in this study were similar to the mean carbohydrate contents of 73.58% and 70.32% reported earlier for unfermented and fermented breadfruit-cowpea blend flours respectively (Ojokoh et al., 2013). Carbohydrate content of 96.91% has been reported for breadfruit flour (Ajani et al., 2012). Values of 62.6 and 61.2% carbohydrate contents have also been reported for nongerminated-nonfermented soy-breadfruit seed and nongerminated-fermented soy-breadfruit seed food formulations respectively (Ariahu et al., 1999). Other researchers also reported reduction in carbohydrate contents of cowpea (Giami, 1993) and various fermented Nigerian legumes and oilseeds (Akpapunam and Achinewhu (1985). The decreased carbohydrate contents recorded for both unfermented and fermented breadfruit-cowpea flour blends due to increase in cowpea flour proportion, could be attributed to the low carbohydrate content of cowpea compared to breadfruit. Furthermore, the reduction in carbohydrate content with fermentation could be due to utilization of fermentable sugars by *Lactobacillus plantarum* for growth and other metabolic

Table 2. Antinutritional contents of fermented and unfermented breadfruit-cowpea flour blends.

Content (mg/100 g)	TvA		TvB		TvC		TvD		TvE		TvF	
	Unfermented	Fermented	Unfermented	Fermented	Unfermented	Fermented	Unfermented	Fermented	Unfermented	Fermented	Unfermented	Fermented
Oxalate	$2.78^{b} \pm 0.02$	$0.90^{a} \pm 0.02$	$2.76^{b} \pm 0.03$	$0.81^{a} \pm 0.02$	$2.70^{b} \pm 0.02$	$0.78^{a} \pm 0.02$	$2.63^{b} \pm 0.03$	$0.75^{a} \pm 0.01$	$2.59^{b} \pm 0.02$	$0.63^{a} \pm 0.03$	$2.36^{b} \pm 0.02$	$0.38^{a} \pm 0.02$
Phytate	$0.91^{f} \pm 0.02$	$0.58^{d} \pm 0.02$	$0.89^{f} \pm 0.03$	$0.56^{cd} \pm 0.02$	$0.84^{f} \pm 0.02$	$0.42^{bc} \pm 0.02$	$0.78^{ef} \pm 0.02$	$0.38^{ab} \pm 0.02$	$0.70^{de} \pm 0.02$	$0.28^{ab} \pm 0.02$	$0.68^{de} \pm 0.02$	$0.24^{a} \pm 0.02$
HCN	$2.73^{c} \pm 0.03$	$0.02^{a} \pm 0.003$	$2.55^{bc} \pm 0.030$	$0.009^{a} \pm 0.002$	$2.48^{bc} \pm 0.02$	$0.006^{a} \pm 0.002$	$2.38^{bc} \pm 0.02$	$0.006^{a} \pm 0.001$	$2.37^{bc} \pm 0.02$	$0.004^{a} \pm 0.001$	$2.28^{b} \pm 0.020$	$0.004^{a} \pm 0.001$

Values are means ± standard deviation of triplicates. Values in the same row with different superscripts are significantly different at $p < 0.05$. TvA = 100:0 breadfruit flour to cowpea flour blend; TvB = 90:10 breadfruit flour to cowpea flour blend; TvC = 80:20 breadfruit flour to cowpea flour blend; TvD = 70:30 breadfruit flour to cowpea flour blend; TvE = 60:40 breadfruit flour to cowpea flour blend; TvF = 50:50 breadfruit flour to cowpea flour blend. HCN = Hydrogen cyanide.

activities (Ojokoh et al., 2013).

Antinutritional contents

Oxalate contents for unfermented and fermented breadfruit-cowpea flour blends ranged from 2.36 - 2.78 mg/100 g and 0.38 - 0.90 mg/100 g respectively (Table 2). Though, the oxalate content decreased with increase in cowpea flour proportion in the breadfruit-cowpea flour blends, the changes were not significantly ($p > 0.05$) different for both unfermented and fermented samples. However, fermentation significantly decreased ($p < 0.05$) the oxalate contents of breadfruit-cowpea flour blends (Table 2). The oxalate contents observed in this study for unfermented breadfruit-cowpea blend flours were similar to values reported in our previous study, which ranged from 2.38 - 2.80 mg/100 g (Ojokoh et al., 2013). However, values for fermented breadfruit-cowpea blend flours were low compared to our previous results of 0.83 - 2.10 mg/100 g. The decreased oxalate contents for both unfermented and fermented breadfruit-cowpea flour blends due to increase in cowpea flour proportion, could be attributed to the low oxalate content of cowpea compared to breadfruit. Also, the reduction in oxalate content with fermentation could be due to the activities of *Lactobacillus plantarum* (Ojokoh et al., 2013).

Phytate contents ranged from 0.59 - 0.93 mg/100 g for unfermented and 0.24 - 0.58 mg/100 g for fermented breadfruit-cowpea flour blends respectively (Table 2). Phytate contents for unfermented TvA, TvB, TvC and TvD were not significantly ($p > 0.05$) different from each other (Table 2). However, values for unfermented TvE and TVF were significantly ($p < 0.05$) different from unfermented TvA, TvB, TvC and TvD. Fermentation significantly decreased ($p < 0.05$) the phytate contents of breadfruit-cowpea flour blends (Table 2). High phytic acid (phytate) contents of 1.76 g/kg and 1.17 g/kg have been reported for nongerminated-nonfermented soy-breadfruit seed and nongerminated-fermented soy-breadfruit seed food formulations respectively (Ariahu et al., 1999). Also, high phytate contents of 143.3 mg/100 g, 125 mg/100 g and 80.13 mg/100 g have been reported for parboiled, boiled and fermented African breadfruit flour (Onweluzo and Nnamuchi, 2009). The phytate contents recorded in the present study for unfermented breadfruit-cowpea blend flours were similar to values reported in our previous study, which ranged from 0.61 - 0.91 mg/100 g (Ojokoh et al., 2013). Ojokoh et al. (2013) also reported reduction in phytate content of breadfruit-cowpea blend flours when spontaneously fermented. The reduction in phytate content with fermentation could partly be due to the activity of *Lactobacillus plantarum* (Ojokoh et al., 2013). Some microflora has been reported to possess phytase which breakdown phytate (Ojokoh, 2005).

Hydrogen cyanide contents for unfermented and fermented breadfruit-cowpea flour blends ranged from 2.28 - 2.73 mg/100 g and 0.004 - 0.020 mg/100 g respectively (Table 2). Hydrogen cyanide contents for unfermented and fermented breadfruit-cowpea flour blends reduced insignificantly ($p > 0.05$) with increase in cowpea proportions (Table 2). However, fermentation significantly decreased ($p < 0.05$) the hydrogen cyanide contents of breadfruit-cowpea flour blends (Table 2). Cyanide contents of 0.03 mg/100 g, 0.02 mg/100 g and 0.02 mg/100 g have been reported for parboiled, boiled and fermented African breadfruit flour (Onweluzo and Nnamuchi, 2009). The hydrogen cyanide contents recorded were similar to values of 2.28 - 2.65 mg/100 g and 0.006 - 0.01 mg/100 g reported for unfermented and fermented breadfruit-cowpea blend flours in our previous study (Ojokoh et al., 2013). The reduction in hydrogen cyanide content with

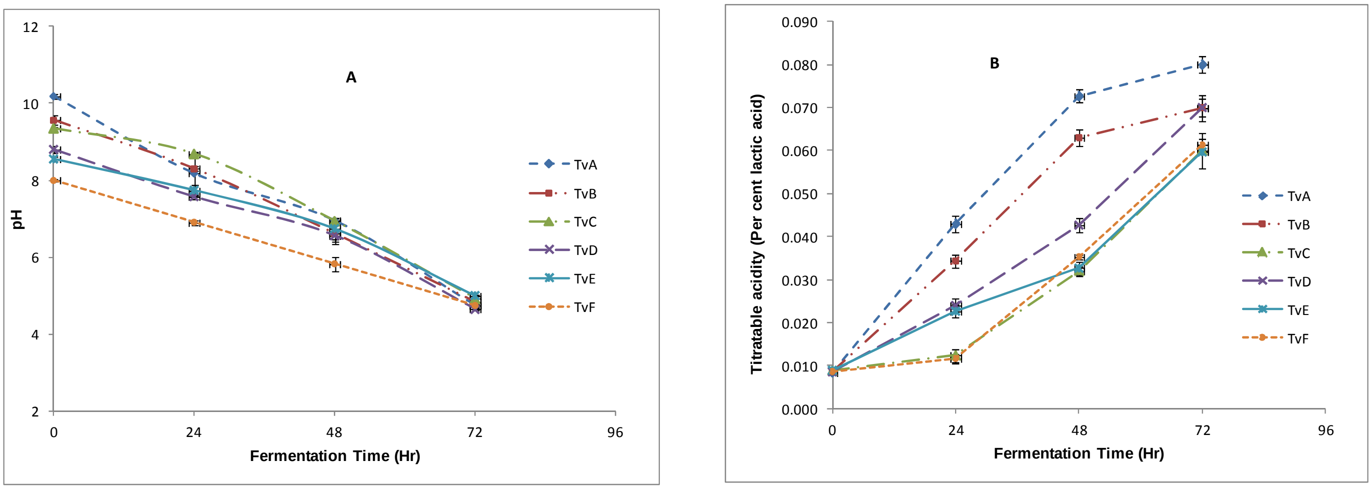

Figure 2. Changes in pH (**A**) and titratable acidity (**B**) of breadfruit-cowpea flour blends during fermentation period. TvA = 100:0 breadfruit flour to cowpea flour blend; TvB = 90:10 breadfruit flour to cowpea flour blend; TvC = 80:20 breadfruit flour to cowpea flour blend; TvD = 70:30 breadfruit flour to cowpea flour blend; TvE = 60:40 breadfruit flour to cowpea flour blend; TvF = 50:50 breadfruit flour to cowpea flour blend. Error bars = ± standard deviations.

fermentation could be attributed to enzyme activities of *Lactobacillus plantarum* (Kobawila et al., 2005).

The reduction in antinutritional contents of the breadfruit-cowpea flour blends after fermentation suggests bioavailability of the rich nutrients present in the fermented products.

Physico-chemical properties

pH for unfermented breadfruit-cowpea flour blends ranged from 7.99 - 10.18 (Figure 2A). Increasing the cowpea flour proportion of the breadfruit-cowpea flour blends significantly decreased ($p < 0.05$) the pH of the samples. The titratable acidity (TTA) (expressed as % lactic acid) for unfermented breadfruit-cowpea flour blends ranged from 0.008 - 0.009 (Figure 2B). Increasing the cowpea flour content of the breadfruit-cowpea flour blends however did not significantly ($p > 0.05$) change the TTA of the samples. The pH values of the breadfruit-cowpea flour blends decreased significantly ($p < 0.05$) with increase in fermentation period (Figure 2A). Also, TTA of the breadfruit-cowpea flour blends significantly ($p < 0.05$) increased with increase in fermentation period (Figure 2B). Similar decrease in pH and increase in TTA due to spontaneous fermentation have been reported for breadfruit-cowpea blend flours (Ojokoh et al., 2013). Ariahu et al. (1999) also reported similar decrease in pH and increase in TTA during fermentation of nongerminated and germinated soy-breadfruit seed food formulations. Amankwah et al. (2009) reported significant decrease in pH and increased titratable acidity in fermented maize flour. The reduction in pH and increase in TTA during fermentation could be attributed to the production of lactic acid by *Lactobacillus plantarum* (Ariahu et al., 1999; Ojokoh et al., 2013). Lactic acid bacteria have been reported to degrade carbohydrates (Table 1) resulting in acidification (Ariahu et al., 1999; Ojokoh et al., 2013). High acidity in fermented legumes has been reported to reduce the incidence of diarrhea among infants (Mensah et al., 1990).

Conclusions

The results from this study show that fermentation of breadfruit-cowpea flour blends using pure strains of *Lactobacillus plantarum* (FO-12) improves the nutritional qualities of the blends. This implies that fermented breadfruit-cowpea flour blends have potentials in the formulation of weaning foods for the management of Protein-Energy Malnutrition (PEM).

Conflict of interests

The author(s) have not declared any conflict of interests.

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