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Fermentation of Cassava (*Manihot esculenta*) and Ripe Plantain Peels (*Musa paradisiaca*) in the Production of Animal Feed

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Authors' contributions

This work was carried out in collaboration between both authors. Author OOF designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the analyses of the study. Author OAO managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To study the effects of fermentation on the nutrient composition of cassava and ripe plantain peels.
Study Design: Raw cassava and ripe plantain peel blends were varied at different ratio (100:0, 70:30, 60:40, 50:50 and 0:100) and fermented for 96 h.
Place and Duration of Study: Department of Microbiology and Department of Animal Production and Health, Federal University of Akure, Ondo State between October 2015 and July 2016.
Methodology: Microbial analysis was carried out using potato dextrose agar, nutrient agar and De man Rogosa agar. pH and total titratable acidity analysis were carried out. Proximate and mineral composition of the blends was also carried out.
Results: A total number of fifteen (15) microorganisms were isolated during the fermentation of cassava-plantain blend; these comprise of four molds (*Penicillium notatum, Aspergillus niger, Aspergillus flavus, Rhizopus stolonifer)*, ten bacteria (*Bacillus subtilis, Lactobacillus plantarum,*

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Lactobacillus fermetum, Pedicoccus acidilactic, Lactobacillus delbrueckii, Micrcoccus luteus, Enterobacter cloacae, Bacillus cereus, Leuconostoc mescenteriodes and *Staphylococcus aureus* and a yeast (*Saccharomyces cerevisae)*. The pH and TTA values of cassava and plantain peel blends varied as the fermentation day progresses. The proximate composition showed an increase in nutritive value of the fermented sample when compared with raw samples. There was significant increase in the mineral composition of the fermented samples when compared with the raw samples.

Keywords: Solid state fermentation; cassava peel; ripe plantain peel; mineral; proximate analysis.

1. INTRODUCTION

Grain production remains insufficient to meet human and animal feeding; the alternative is to employ feed ingredients which do not have direct human value. Agricultural wastes are renewable resource of great variety of biotechnological potential [1]. In recent years, waste like rice straw, rice hulls, fruit wastes, cassava peels and starch residues have been used as substrates for growing microbes also in ruminant feeding which appears to be the available option left for farmers in addressing the problem of competition between human beings and animals for conventional feed ingredients [2]. Peels are the major by-products obtained during the processing of various fruits and these were shown to be a very good source of polyphenols, caroteinoids, dietary fibres, and other bioactive compounds which possess various beneficial effects on human health [3].

Cassava peel is a major by-product generated from cassava processing into its various domestic and industrial uses. Cassava peel is an important source of energy in ruminant feeding systems, serving either as the main basal diet or as a supplement. These peels are usually not good as animal feed, due to their high fibre and low protein contents [4,5]. For cassava peels to be used as a substitute for cereal in animal feeding, they must be supplemented, either with protein-rich oilseed, fish meals or by using microbial techniques. The microbial enrichment process is relatively cheap and the enriched product can increase the potential of cassava as a feed [6].

Plantain peels are good sources of vitamins and minerals [7], particularly iron (24 mg/kg), potassium (9.5 mg/ kg), calcium (715 mg/kg), vitamin A, ascorbic acid, thiamin, riboflavin and niacin [8]. Plantain pulp is low in protein with estimated values of 4 g/kg in green unripe finger and 9 g/kg in the fully ripe finger. The sodium content (351 mg/kg) is low in dietary terms hence recommended for low sodium diets [9]. The amino acid components include; alanine, aminobutyric acid, glutamine, asparagine, histidine, serine, arginine and leucine. The ascorbic acid is high compared to that of banana. As a starchy staple food, plantain supply about 1 g protein/100 g edible portion [10]. Since these peels could make up to 10% of the wet weight of the roots, they constitute an important potential resource for animal feeds if properly processed by a bio-system [11].

The constraints to their use in livestock nutrition are their high fibre content, low calorific value and their heavy loads of anti-nutrients like cyanide, tannins and phytates [12]. Fermentation of food products is an effective method of improving the starch and protein digestibility and brings down the level of anti-nutrients [12]. Fermentation of these peels will help to reduce the anti-nutrients and increase the nutritional values of these agro by- products used as animal feeds, hence the need for this research.

2. METHODOLOGY

2.1 Collection of Samples

Fresh plantain (*Musa paradisiaca*) was obtained from “Oba” market in Akure, while fresh Cassava peels (*Manihot esculenta*) were provided by a Garri Processing Factory at Ilara-Mokin, Ondo State.

2.2 Processing and Formulation of Blends

The plantain and cassava peels were washed, sun dried, milled and formulated in the ratio of (cassava: ripe plantain).

A (50:50) = 50 gram of cassava peel and 50 g of ripe plantain peel
B (60:40) = 60 gram of cassava peel and 40 g of ripe plantain peel
C (70:30) = 70 gram of cassava peel and 30 g of ripe plantain peel
D (0:100) = 100 g of ripe plantain peel
E (100:0) = 100 g of cassava peel.

2.3 Fermentation of Blends

This was achieved by using solid state fermentation technique method (90 ml of cooled sterile distilled water to 100 g of the blend). This was covered tightly and allowed to ferment for 96 hours. The fermented peels were subsequently analyzed daily.

2.4 Determination of pH and Total Titratable Acidity (TTA)

Daily recording of the temperature and pH of the samples were taken throughout the period of the experiment. 10 g of each sample was suspended in 90 mls sterile distilled water and homogenized. The pH was ascertained using the pH meter metrom E520. The TTA analysis was done using [13] method. A 10 ml of the sample was pipetted into a beaker and 3 drops of Phenolphthalein indicator was added. Titration was done using 0.1M NaOH to a faint pink colour for at least one minute compared against a white background. The acidity was calculated as follows:

$$\% \text{ acid} = \frac{\text{Titre value x Normality of Alkali x 9}}{\text{Volume of sample}}$$

Normality of alkali = 0.1

2.5 Microbiological Analysis

Samples of the homogenized mixture were collected for microbial enumeration at 24 hourly intervals until the fermentation was completed. Ten (10) fold serial dilution containing 9 ml of sterile distilled water and 10 g of the fermented samples was inoculated and pour-plated for the enumeration of viable counts from dilution factors of 10^{-2} and 10^{-10} on Petri dishes containing Potato Dextrose Agar, De Man Rogosa and Sharpe agar and nutrient agar plates in duplicate. The culture was incubated at 25 – 28℃. MRS plates were incubated microaerobically in an anaerobic jar at 30℃ for 3-5 days, PDA plates were incubated aerobically at room temperature (25±2℃) for 2-3 days; a pure culture of the desired strain was obtained after series of streaks on all the media. The isolates were characterised based on biochemical and morphological features according to Cowan and Steel [14]. Fungi isolates were identified according to [15].

2.6 Determination of Proximate Analysis

Moisture content was determined by using the oven drying method which is based on weight loss and expressed as % moisture content [13]. Crude protein was determined from the total nitrogen (TN) determined by the micro- Kjeldahl method by multiplying the total nitrogen by a factor of 6.25. Crude fat was determined by using the Soxhlet extraction method using petroleum ether as the solvent [13]. Ash was determined according to [13]. Carbohydrate was determined by difference.

2.7 Determination of Mineral Composition

The mineral composition of the raw flour blends and fermented blends were determined using the methods described by [13]. A 1 g of each sample was ashed in muffle furnace at 550℃ for 120 minutes. The ashed sample and dishes were removed and transferred into the desiccator to cool after which the samples were dissolved with 10 ml of 20% nitric acid (HNO_3). The content was filtered into a clean small plastic bottle using number 43 whatman filter paper. Distilled water was later added to dilute the solution up 50ml. Atomic absorption spectrophotometer was used in determining the concentration of the metals: iron (Fe), zinc (Zn) and calcium (Ca) while flame photometry method was used for determination of Sodium (Na) and potassium (K).

2.8 Statistical Analysis

All data obtained were carried out in triplicates and subjected to descriptive statistics, analysis of variance (ANOVA) and Duncan Multiple Range Test and the level of significance was set at $p \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Microbial Growth during Fermentation of Cassava and Ripe Plantain Peel Blends

Fifteen microorganisms were isolated from the fermented mash of cassava-ripe plantain peels which were characterized by series of biochemical tests and identified. Tables 1 to 3 shows the biochemical test carried out on all the microorganisms isolated. Five (5) fungi identified were: *Penicillium notatum, Saccharomyces cerevisiae, Aspergillus niger, Aspergillus flavus, Rhizopus stolonifer* while the ten (10) bacterial species isolated were: *Bacillus subtilis, B. cereus, Lactobacillus plantarum, Lb. fermetum, Lb. delbrueckii, Pedicoccus acidilactic, Micrococcus luteus, Enterobacter cloacae, Leuconostoc mescenteriodes* and *Staphylococcus aureus.*

Table 1. Biochemical characteristics of bacteria isolated during fermentation of cassava and ripe plantain peel blends

Gram reaction	Cellular morphology	Motility	Oxidase	Indole	Urease	Catalase	Methyl Red	Citrate	Nitrate reduction	Sugar fermentation							Suspected microorganism
										Starch	Glucose	sucrose	Lactose	Fructose	Mannitol	Sorbitol	
+	*Rod*	-	-	-	-	-	-	+	-	+	+	+	+	+	+	+	*Lactobacillus plantarum*
+	*Rod*	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	*Lb. delbrueckii*
+	*Rod*	-	-	-	-	-	-		-	+	+	-	+		-	-	*Lb fermetum*
+	*Cocci*	-	-	-	-	-	-	+	-	-	+	-	-		-		*Pedicoccus acidilactic*
+	*Cocci*	-	-	+	+	+	+	+	+	+	+	+	+		+	+	*Staphylococcus aureus*
-	*Rod*	+	+	-	-	-	-	+	-	+	+	-	+	+	+	+	*Bacillus subtilis*
+	*Rod*	+	+	-	-	-	-	+	+	+	+	-	-	+	-	-	*B. cereus*
+	*Cocci*	-	-	-		+	-	+	-	-	-	-	+	-	+	-	*Micrococcus letus*
+	*Cocci*	-	-	-	-	-	+	+	-	+	-	-	+	-	-	-	*Leuconostoc mesenteroides*
-	*Rod*	+	-	-	-	+	-	+	+	+	+	-	+	+	+	+	*Enterobacter cloacae*

Key: += Positive, - = Negative

Table 2. Biochemical characteristics of yeast isolated during fermentation of cassava and plantain peel blends

Pigment and cellular morphology	Microscopy	Citrate	Catalase test	Gram staining	Urease test	Glucose	Sucrose	Lactose test	Indole test	Suscepted microogranism
Milky white colour, round and serrated edges, moist and raised colonies.	Internal budding and thick ovoid cells singly and in clusters	+	+	+	+	+	+	-	-	*Saccharomyces cerevisiae*

Key: += Positive, - = Negative

Table 3. Characterization of moulds isolated during fermentation of cassava and plantain peel blends

Colony morphology on agar	Microscopic morphology	Suspected microorganism
Green, round raised with egdes	Septate and branched hyphae. Hair like conidiophores	*Penicillum notatum*
Yellow green colonies	The conidia were globose in shape, the hyphae branched and septate conidiophores were long, rough, septate and granular. They have rough surface and they occurred singly and in chains of two and three	*Aspergillus flavus*
Whitish fluffy and cottony in texture. The colony turned brown as it aged.	Erect sporangiosphores were smooth walled, aseptate and light brown in colour.	*Rhizopus stolonifer*
Dark brown colonies	The mycelium appeared whitish at first, frequently developed areas which were bright yellow. Dark brown to black heads were compact radiate, dark brown and biseriated.	*Aspergillus niger*

3.2 Changes in the Bacterial Population during Fermentation of Cassava and Ripe Plantain Peel Blends

Fig. 1 shows changes in the bacterial population of the peel blends during fermentation for 96 h. The initial aerobic count of sample A (50 g Cassava / 50 g plantain) at 0 h was 1.50×10^4 CFU/g and increased to 3.50×10^4 CFU/g and 5.90×10^4 CFU/g at 24 and 48 h respectively, which was followed by a decrease to 4.5×10^4 CFU/g and 2.8×10^4 CFU/g at 72 and 96 h respectively. Sample B (60 g Cassava /40 g plantain) had an initial count of 3.0×10^4 CFU/g at 0 h which increased to 5.1×10^4 CFU/g and 7.5×10^4 CFU/g at 24 and 48 h respectively with a decrease to 5.6×10^4 CFU/g and 3.9×10^4 CFU/g at 72 and 96 h. The aerobic count of Sample C (70 g Cassava/30 g plantain) at 0 hour was 1.9×10^4 CFU/g with a slight increase to 4.4×10^4 CFU/g and 6.5×10^4 CFU/g at 24 and 48 h respectively with a decrease to 4.1×10^4 CFU/g and 1.8×10^4 CFU/g at 76 and 96 h. At 0 h, sample D (100 g plantain peel) had a count of 2.0×10^4 CFU/g with a slight increase to 2.3×10^4 CFU/g at 24 h with a decrease in count to 1.9×10^4 CFU/g at 48 h and increased to 4.9×10^4 CFU/g at 72 h and later decreased to 2.9×10^4 CFU/g at 96 h. The aerobic bacteria count in sample E (100 g cassava peel) was recorded as 2.1×10^4 CFU/g at 0 h and increased to 3.3×10^4 CFU/g, 6.3×10^4 CFU/g and 7.5×10^4 CFU/g at 24, 48 and 72 h. A slight decrease of 3.3×10^4 CFU/g was observed at 96 h.

3.3 Changes in the Lactic Acid Bacteria Population during Fermentation of Cassava and Ripe Plantain Peel Blends

The changes in lactic acid bacteria (LAB) population during fermentation for 96 h are shown in Fig. 2. There was no LAB growth recorded at 0 hour for all the samples. Sample A (50 g Cassava /50 g plantain), had an initial growth of 1.9×10^4 CFU/g at 24 h and increased to 3.2×10^4 CFU/g and 3.8×10^4 CFU/g and 4.40×10^4 CFU/g at 48, 72 and 96 h respectively. Sample B (60 g cassava /40 g plantain) had an initial growth of 1.0×10^4 CFU/g at 24 h and increased to 1.5×10^4 CFU/g, 2.8×10^4 CFU/g at 3.0×10^4 CFU/g at 48, 72 and 96 h respectively. LAB count in sample C (70 g Cassava / 30 g plantain) increased from 2.7×10^4 CFU/g at 24 h to 3.3×10^4 CFU/g, 4.8×10^4 CFU/g, 5.0×10^4 CFU/g at 48, 72 and 96 h respectively. LAB count observed in sample D (100g plantain) had an initial growth of 2.2×10^4 CFU/g at 48 h and increased to 4.6×10^4 CFU/g and 5.0×10^4 CFU/g at 72 and 96 h. Sample E (100 g cassava) had an initial growth of 1.2×10^4 CFU/g at 0 hand increased to 2.5×10^4 CFU/g, 3.1×10^4 CFU/g and 3.9×10^4 CFU/g at 48, 72 and 96 h respectively.

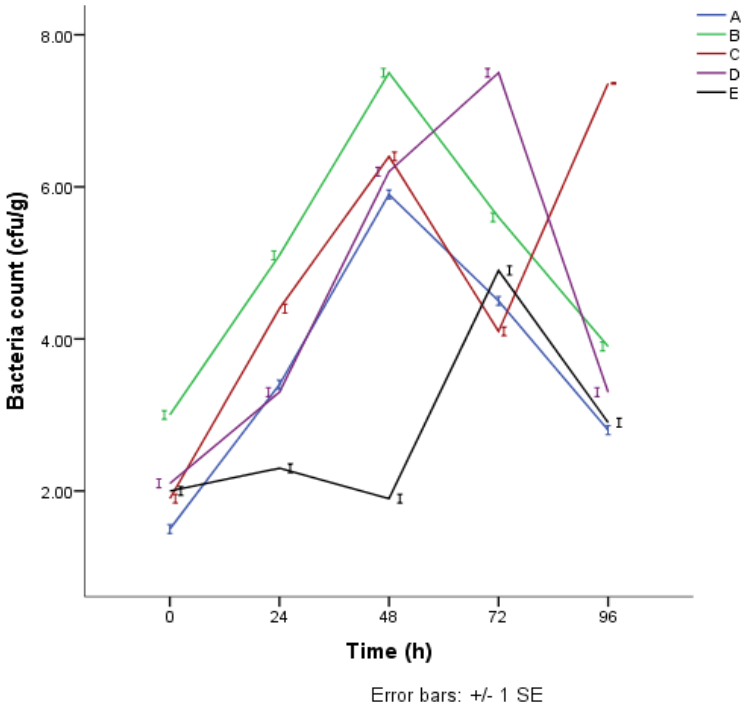

Fig. 1. Changes in bacteria count during fermentation of cassava and plantain peel blends
Keys: A: 50 g Cassava and 50 g Plantain, B: 60 g Cassava and 40 g plantain, C: 70 g Cassava and 30 g Plantain, D: 100 g Plantain, E: 100 g Cassava

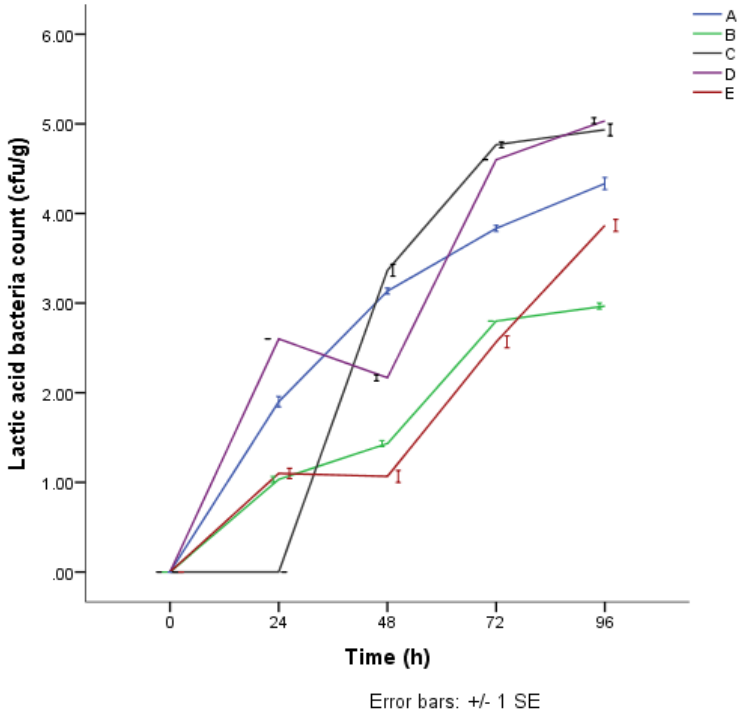

Fig. 2. Changes in lactic acid bacteria count during fermentation of cassava and plantain peel
Keys: A: 50 g Cassava and 50 g Plantain, B: 60 g Cassava and 40 g plantain, C: 70 g Cassava and 30 g Plantain, D: 100 g Plantain, E: 100 g Cassava

3.4 Changes in the Fungal Population during Fermentation of Cassava and Ripe Plantain Peel Blends

Changes in the fungal population of the blend during fermentation for 96 h are shown in Fig. 3. There was no fungal growth recorded at 0 hour for all the samples. Sample A (50 g Cassava/50 g plantain), had an initial fungal count of 1.22 × 10^3 CFU/g at 24 hand increased to 2.32 × 10^3 CFU/g, 2.67 × 10^3 CFU/g, 4.10 × 10^3 CFU/g at 48, 72, 96 h respectively. Sample B (60 g cassava/40 g plantain), experienced no growth at 24 hours. At 48 hours, there was a fungal count of 2.10 × 10^3 CFU/g, which increased at 72 and 96 h (3.78 × 10^3 CFU/g and 4.60 × 10^3 CFU/g). Fungal count in Sample C (70 g Cassava/30 g plantain) had an initial fungal count of 2.34 × 10^3 CFU/g at 24 hand increased to 2.90 × 10^3 CFU/g, 3.71 × 10^3 CFU/g and 4.43 × 10^3 CFU/g at 48, 72 and 96 h respectively. Fungal count observed in Sample D (100 g plantain) increased at 24 to 96 h (2.00 × 10^3 CFU/g, 2.60 × 10^3 CFU/g, 3.24 × 10^3 CFU/g and 4.18 × 10^3 CFU/g). Sample E (100 g cassava) experienced increase in fungal growth at 24 to 96 h (1.25 × 10^3 CFU/g, 1.80 × 10^3 CFU/g, 2.60 × 10^3 CFU/g and 3.01 × 10^3 CFU/g).

3.5 Bacteria Occurrence during Fermentation of Cassava and Ripe Plantain Peel Blends

Bacillus subtilis was the most frequently isolated bacteria followed by the *Lactobacillus* sp. Occurrence of the major bacterial species isolated is shown in Table 4. *Bacillus subtilis* was isolated from 50 g Cassava and 50 g Plantain peel blend (Sample A) at 0, 48, 72 and 96 h. It was also isolated from 70 g Cassava and 30 g Plantain peel blend (Sample C) and 100 g Plantain peel blend (Sample D) at 48 and 24 h respectively at 48, 72 and 96 h, 100 g Cassava peel blend (Sample E) at 24, 72 and 96 h. *Bacillus cereus* was isolated from sample B and sample C at 0 and 24 h. M*icrococcus luteus* was isolated only from sample D at 0 h. *Enterobacter cloacae* was isolated from sample B at 48 h. *Staphylococcus aureus* was isolated from sample B and sample C at 24 and 48 h, Sample D at 24 hand sample E at 0 h. *Leuconostoc mesenteriodes* was isolated in sample D at 96 h. *Lactobacillus plantarum* was isolated from sample A at 48 and 72 h, sample B at 24 h, sample C at 96 h and sample E at 48 h. *Lactobacillus delbrueckii* was isolated from sample E at 48 and 72 h. *Lactobacillus fermentum* was isolated from sample B at 48, 72 and 96 h and sample D at 24, 48 and 72 h.

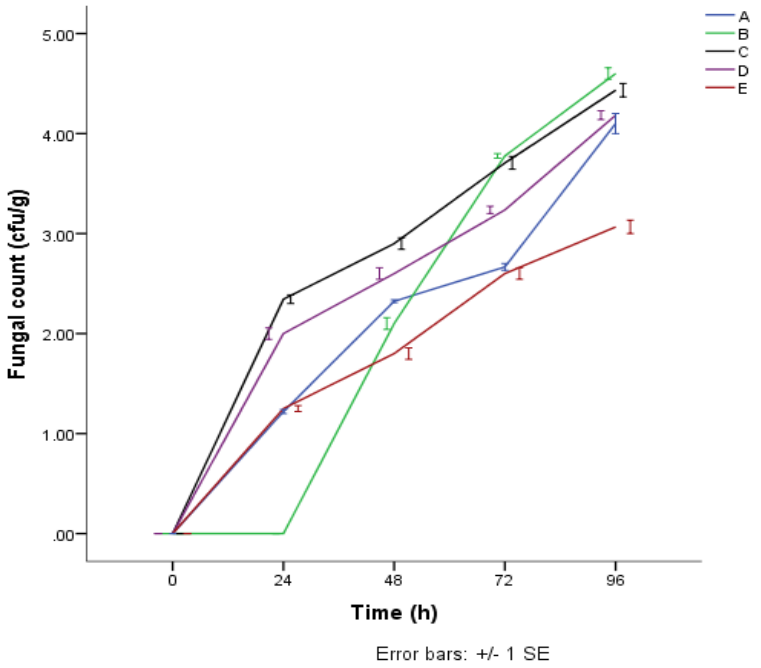

Fig. 3. Changes in fungal counts during fermentation of cassava and plantain peel blends

Keys: A: Fermented 50 g cassava/50 g plantain, B: Fermented 60 g cassava /40 g plantain, C: Fermented 70 g cassava/ 30 g plantain, D: Fermented 100 g plantain, E: Fermented 100 g cassava

Table 4. Bacteria succession during fermentation of cassava and ripe plantain peels blends

Samples	Time(h)				
	0	**24**	**48**	**72**	**96**
A	*Bacillus subtilis*	*Lactobacillus plantarum, Staphylococcus aureus*	*Bacillus subtilis, Lb. plantarum*	*B. subtilis, Lb. plantarum*	*B. subtilis, Pedicococcus acidilactic*
B	*Bacillus cereus*	*B. cereus, Lb. plantarum*	*Lb. fermentum, Enterobacter cloacae*	*Lb. fermentum, B. cereus*	*Lb. fermentum*
C	*Bacillus cereus*	*B. cereus, Staphylococcus aureus*	*Pedicococcus acidilactici*	*P. acidilactici,*	*B. subtilis. Lactobacillus plantarum*
D	*Micrococcus luteus*	*S. aureus Lb. fermentum*	*B. subtilis Lb. fermentum*	*B. subtilis, Lb. fermentum*	*B. subtilis. Leuconostoc mesenteriodes*
E	*S. aureus*	*B. subtilis, Lb. delbrueckii*	*Lb. plantarum*	*B. subtilis, Lb. delbrueckii*	*B. subtilis, Lb. delbrueckii*

Keys: A: 50 g cassava/50 g plantain, B: 60 g cassava /40 g plantain, C: 70 g cassava/ 30 g plantain, D: 100 g plantain, E: 100 g cassava

Table 5. Fungal succession during fermentation of cassava and ripe plantain peels blends

Samples	Time(h)				
	0	**24**	**48**	**72**	**96**
A	-	*Aspergillus niger*	*Aspergillus flavus, Penicillum notatum*	*Aspergillus flavus Saccharomyces cerevisiae*	*Saccharomyces cerevisiae*
B	-	*Saccharomyces cerevisiae Aspergillus niger*	*Saccharomyces cerevisiae, Aspergillus niger*	*Saccharomyces cerevisiae*	*Saccharomyces cerevisiae*
C	-	*Saccharomyces cerevisiae, Aspergillus niger*	*S. cerevisiae*	*S. cerevisiae*	*S. cerevisiae*
D	-	*Aspergillus flavus Rhizopus stolonifer*	*S. cerevisiae*	*S. cerevisiae*	*S. cerevisiae*
E	-	*S. cerevisiae, A. niger*	*S. cerevisiae*	*S. cerevisiae*	*S. cerevisiae*

Keys: A: Fermented 50 g cassava/50 g plantain, B: Fermented 60 g cassava /40 g plantain, C: Fermented 70 g cassava/ 30 g plantain, D: Fermented 100 g plantain, E: Fermented 100 g cassava

3.6 Fungal Occurrence during Fermentation of Cassava and Ripe Plantain Peel Blends

Table 5 shows the changes in the fungal population of the peel blends during fermentation. There was no growth at 0 r. *Aspergillus niger* was also isolated from sample A at 24 h, sample B at 24 and 48 h, sample C at 24 h and sample E at 24 h. *Aspergillus flavus* was isolated from sample A at 48 h and sample D at 24 h. *Penicillum notatum* was isolated from sample FA at 48 h. *Saccharomyces cerevisiae* was isolated from sample A at 72 and 96 h, sample B, C and E at 24, 48, 72 and 96 h, sample D at 48, 72 and 96 h.

3.7 Changes in pH during Fermentation of Cassava and Ripe Plantain Peel Samples

Fig. 4 shows the effect of pH in the fermented peel blends. As the fermentation reaction progresses, all the sample peel showed a drop in the pH value from 0 hour till 96 h of the fermentation. Sample E (100 g Cassava) recorded the lowest pH value at 96 h with a mean of 4.01, the highest recorded at 0 h in Sample D (100 g Plantain) with a mean of 7.20.

3.8 Changes in Total Titrable Acidity during Fermentation of Cassava and Ripe Plantain Peel Blends

Fig. 5 shows the Total Titratable acidity values for the entire fermented blend. At 0 h, the TTA values increased and decreased at 48 h and increased at 72 h. The highest TTA was recorded in Sample D (70 g cassava/30 g plantain) with a value of 0.15% at 96 h while the lowest TTA was recorded in Sample A (50 g cassava/ 50 g plantain) with a value of 0.062% at 0 h.

3.9 Proximate Composition of Fermented and Raw Cassava and Ripe Plantain Peel Blends

Table 6 shows the proximate analysis. There was significant difference in the mean values of all the blends.

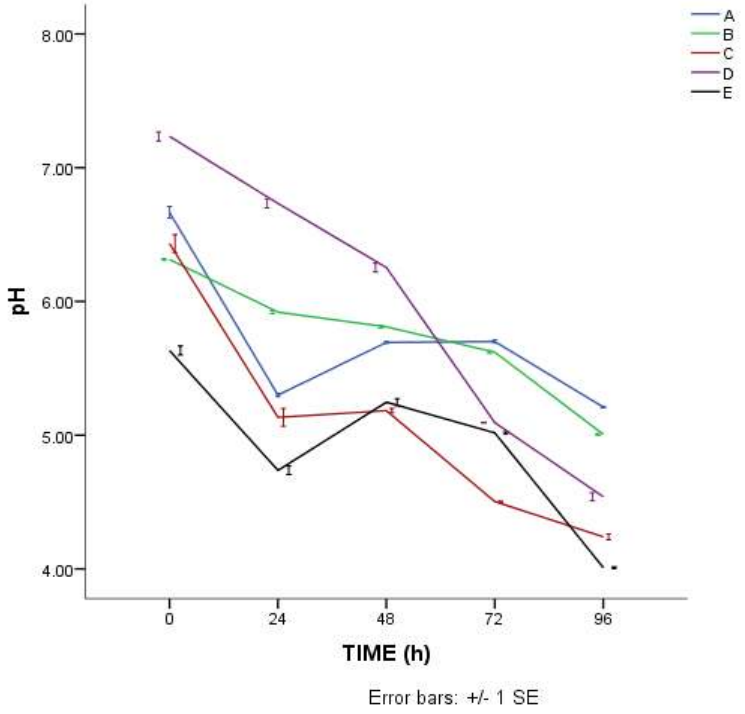

Fig. 4. pH variation during fermentation of cassava and plantain peel blend
Keys: A: 50 g Cassava/50 g Plantain, B: 60 g Cassava/40 g plantain, C: 70 g Cassava/30 g Plantain D: 100 g Plantain, E: 100 g Cassava

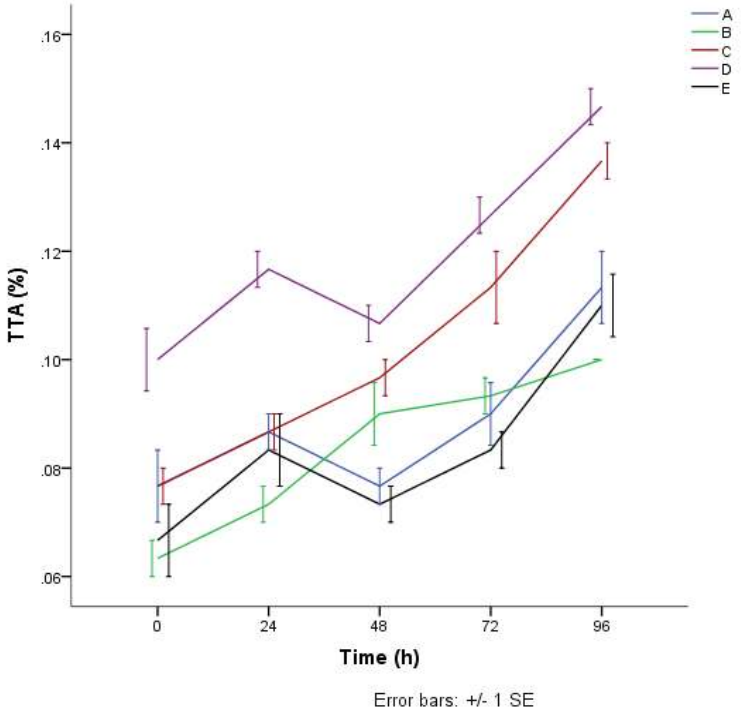

Fig. 5. Total titratable acidity variation during fermentation of cassava and plantain peel blend
Keys: A: 50 g cassava/50 g plantain, B: 60 g cassava /40 g plantain, C: 70 g cassava/ 30 g plantain D: 100 g plantain, E: 100 g cassava

The raw blends were significantly higher in moisture content compared to the fermented blends. The highest moisture content was recorded in RD (100 g plantain peel) with a mean value of 8.85±0.02 while the lowest was FE (100 g cassava peel) with a mean value of 7.04±0.03.

The fermented blends had the highest ash content compared to that of the raw blends. The highest ash content was recorded in FD (fermented 100 g plantain) with mean value of 17.06±0.21 while the lowest was recorded in RB (fermented 60 g cassava/ 40 g plantain) with mean value of 9.86±0.30.

Raw blends had the highest fat content compared to that of the fermented blends. The highest Fat content was recorded in RD (100 g plantain peels) with mean value of 8.99±0.33 while the lowest was recorded in FE (fermented 100 g cassava peels) with mean value of 3.27±0.06.

Raw blends had the highest fibre content compared to that of the fermented blends. The highest fibre content was recorded in RE (Raw 100 g cassava peels) with a mean value of 22.91±0.38 while the lowest was recorded in FD (fermented 100 g plantain) with mean value of 7.00±0.28.

The fermented blends had the highest protein content compared to raw blends. The highest protein content was recorded in FA (fermented 50 g cassava peels and 50 g plantain peels) with a mean value of 25.05±0.05 while the lowest was recorded in RE (100 g cassava peels) with mean value of 12.51±0.01.

The fermented blends had the highest carbohydrate content compared to raw blends except for FB which recorded a decrease in carbohydrate content. The highest carbohydrate content was recorded in FE (fermented 100 g cassava peels) with a mean value of 50.01±0.16 while the lowest was recorded RD (100 g plantain peels) with a mean value of 32.25±0.37.

3.10 Mineral composition of the blends

Table 7 above shows the mineral composition of the fermented and raw blends. Sodium (Na) content was highest in FB (60 g cassava/40 g

plantain) with a mean value of 19.80±0.11. The lowest in Sodium content was recorded in RD (100 g plantain) with a mean value of 11.12±0.01.

Calcium (Ca) content was recorded highest in FD (100 g plantain) with a mean value of 82.30±0.01 and the lowest was recorded in RE (100 g cassava) with a mean value of 29.46±0.03.

Potassium (K) content was highest in FD (100 g plantain) with a mean value of 33.50±0.01 and the lowest recorded in RA (50 g cassava/50 g plantain) with mean value of 10.05±0.03.

Table 6. Proximate composition of fermented and raw cassava and plantain peel blend

Sample (g)	Moisture (%)	Ash (%)	Fat (%)	Fibre (%)	Protein (%)	CHO (%)
FA	7.51±0.03^{bc}	16.41±0.32^{e}	4.27±0.06^{de}	10.82±0.19^{c}	25.05±0.05^{i}	35.94±0.47^{c}
FB	8.05±0.09^{ef}	16.76±0.14^{ef}	4.51±0.11^{ef}	8.40±0.30^{b}	22.41±0.01^{h}	39.86±0.37^{c}
FC	7.11±0.14^{a}	15.70±0.04^{d}	3.88±0.02^{bc}	13.71±0.26^{d}	18.38±0.16^{g}	41.21±0.29^{cd}
FD	8.39±0.08^{g}	17.06±0.21^{f}	3.55±0.08^{ab}	7.00±0.28^{a}	16.33±0.11^{e}	47.66±0.56^{fg}
FE	7.04±0.03^{a}	16.50±0.06^{ef}	3.27±0.06^{a}	7.50±0.15^{a}	15.66±0.01^{d}	50.01±0.16^{g}
RA	7.89±0.07^{de}	12.33±0.14^{b}	4.74±0.02^{f}	22.32±0.22^{g}	17.20±0.16^{f}	35.51±0.32^{b}
RB	8.28±0.01^{fg}	9.86±0.30^{a}	5.24±0.04^{g}	19.06±0.04^{e}	14.17±0.23^{c}	43.37±0.52^{de}
RC	7.32±0.11^{ab}	14.15±0.12^{c}	5.71±0.14^{h}	20.49±0.22^{f}	17.52±0.04^{f}	34.81±0.03^{b}
RD	8.85±0.02^{h}	16.25±0.05^{de}	8.99±0.33^{i}	20.09±0.27^{f}	13.60±0.21^{b}	32.25±0.37^{a}
RE	7.72±0.24^{cd}	10.01±0.29^{a}	4.08±0.04^{cd}	22.91±0.38^{g}	12.51±0.01^{a}	45.76±2.32^{ef}

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

Keys: RA: Raw 50 gram cassava/ 50 gram plantain peel, RB: Raw 60 gram cassava/40 gram plantain peel, RC: Raw 70 gram cassava/30 gram plantain peel, RD: Raw 100 gram plantain peel, RE: Raw 100 gram cassava peel, FA: Fermented 50 gram cassava/ 50 gram plantain peel, FB: Fermented 60 gram cassava/40 gram plantain peel, FC: Fermented 70 gram cassava/30 gram plantain peel, FD: Fermented 100 gram plantain peel, FE: Fermented 100 gram cassava peel and CT: Control

Table 7. Mineral composition of fermented and raw cassava and plantain peel blends

Samples	Na (PPM)	Ca (PPM)	K (PPM)	Zn (PPM)	Fe (PPM)
FA	13.10±0.01^{d}	77.20±0.01^{i}	22.97±0.04^{f}	0.63±0.01^{d}	24.30±0.01^{g}
FB	19.80±0.11^{f}	71.20±0.01^{g}	25.02±0.01^{g}	0.91±0.01^{f}	20.00±0.01^{f}
FC	17.00±0.01^{e}	72.71±0.01^{h}	30.02±0.01^{h}	0.85±0.01^{e}	19.50±0.01^{e}
FD	11.81±0.01^{b}	82.30±0.01^{j}	33.50±0.01^{i}	0.45±0.02^{b}	15.30±0.01^{c}
FE	12.90±0.01^{d}	36.50±0.01^{b}	21.63±0.31^{e}	0.85±0.01^{e}	20.00±0.01^{f}
RA	11.64±0.01^{b}	59.00±0.01^{d}	10.05±0.03^{a}	0.55±0.02^{c}	20.60±0.01^{g}
RB	11.87±0.34^{b}	69.10±0.01^{c}	15.62±0.31^{cd}	0.57±0.01^{c}	15.10±0.01^{b}
RC	11.52±0.01^{b}	59.50±0.01^{f}	15.34±0.34^{c}	0.62±0.01^{d}	18.00±0.01^{d}
RD	11.12±0.01^{a}	50.30±0.01^{c}	16.03±0.02^{d}	0.37±0.01^{a}	14.22±0.02^{a}
RE	12.20±0.01^{c}	29.46±0.03^{a}	12.92±0.02^{b}	0.65±0.01^{d}	19.50±0.01^{e}

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

Keys: RA: Raw 50 gram cassava/ 50 gram plantain peel, RB: Raw 60 gram cassava/40 gram plantain peel, RC: Raw 70 gram cassava/30 gram plantain peel, RD: Raw 100 gram plantain peel, RE: Raw 100 gram cassava peel, FA: Fermented 50 gram cassava/ 50 gram plantain peel, FB: Fermented 60 gram cassava/40 gram plantain peel, FC: Fermented 70 gram cassava/30 gram plantain peel, FD: Fermented 100 gram plantain peel, FE: Fermented 100gram cassava peel, CT: Control

Zinc (Zn) content was highest in FB (60 g cassava/ 40 g plantain) with a mean value of 0.91±0.01 and the lowest in zinc content was recorded in RD (100 g plantain) with mean value of 0.37±0.01.

Iron (Fe) content was recorded highest in FA (fermented 50 g cassava /50 g plantain) with a mean value of 24.30±0.01 and the lowest in Fe content was recorded in RD (raw 100 g plantain) with mean value of 14.22±0.02.

4. DISCUSSION

In this study, the microbial load increased with increase in fermentation time. The increase in microbial loads could be attributed to the availability of water and source of microorganisms. As the duration of fermentation progresses, a decrease in the growth of bacteria was observed between 48 and 72 h. The decrease could be due to reduction in the pH value, utilization of available nutrients such as water and antagonistic association between the fermenting microorganisms.

The pH of the fermenting substrates decreased with increase in fermentation time. The pH of the fermenting same ranged from 7.20- 4.01. The decrease in the pH value of the fermented samples may be due to the abundant production of organic acid such lactic acid produced by lactic acid bacteria and some yeast [16,12]. The multiplication of microbes in the system might be responsible for acid neutralization with increase in consumption of nutrients in the fermenting substrates. This study is in agreement with the findings of [17] who observed a decrease in the pH during the fermentation of breadfruit- cowpea flour blends. [18] also reported a decrease in pH during the fermentation of corn- groundnut blends. Similar report was observed by [12] the fermentation of cassava peel with *Aspergillus niger.*

The titratable acidity increased with increase in fermentation time. The total titratable acidity ranged from 0.06- 0.15. The increase in titratable acidity could be due to the proliferation of lactic acid bacterial in the fermenting medium that are capable of hydrolyzing the substrate (carbohydrates) thereby resulting in its acidification. The increase in titratable acidity of the fermenting samples was in agreement with the findings of [18] who reported an increase in the titratable acidity of fermentated corn-groundnut blend.

Protein is needed for normal body growth, repairs and maintenance. A relatively high amount of protein is therefore required for functional foods and nutraceuticals, because they are used basically for supplementation. The protein content of the fermenting substrates increased with increase in fermentation time. Increase in crude protein content might be as a result of secretion of extra cellular enzymes by the fermenting organisms into the fermenting medium, as well as the growth and proliferation of the fungi in the form of single cell protein [19,20]. An increase in protein content of the plant foods was reported by [21]. Similar observation was reported by [17] during fermentation of breadfruit (*Treculia africana)* and cowpea *(Vigna unguiculata)* blend flours. [12] had also reported an increase in protein content of cassava peel fermented with *Aspergillus niger* the result obtained from this study corroborate the findings of [22], which gave clear evidence of enrichment of cassava products through fermentation.

Fat is the one of the major components of food that provides essential lipids and energy. The lipid content of cassava and ripe plantain peel samples showed a consistent decrease with increase in fermentation time. The decrease in total lipid could be due to the breakdown of lipid by the microorganisms in the fermented sample. The decrease in fat content might be due to different microorganisms employed in the fermentation. The result obtained was in contrary to findings of [23] who reported an increase in the lipid during the enrichment of cassava with microbial protein.

The fibre content decreased with fermentation time. The decrease in crude fibre content might be due to the ability of the fermenting microorganisms to degrade the crude fibre of fermenting mash. Microbes have been shown to degrade crude fibre to volatile fatty acids, methane, and produce microbial biomass [12]. The result obtained was similar to the findings of [12] who reported a decrease in the fibre content of cassava peels fermented with *Aspergillus niger.*

The moisture content of the samples decreased with fermentation. This decrease could be attributed to the fact that the micro-organisms utilized the substrates moisture for growth and metabolism [24]. The decrease in moisture content with increase in fermentation time might be due to the soft and porous texture of the mash after fermentation resulting in maximum moisture

loss. The microorganisms must have utilized some moisture for metabolic activities [25]. The low value of moisture content observed in this study would enhance the storability and keeping quality of the feed.

Ash content is indicative of the amount of minerals in any food sample. There was an increase in ash content which could be as a result of the degrading activity of the fungi [26,27]. [28] reported that the increase in the ash content of the fermented cassava waste could have been as a result of the hydrolysis of such chelating agents like phytate which is highly concentrated in cassava tuber waste products during microbial fermentation.

An increase in carbohydrate content was observed in the fermented sample except for FB (fermented 60% cassava/40% plantain peel). The increase in carbohydrate content during fermentation may be due to a reduction in the fibre content and increase in both reducing sugars and total soluble sugars [29]. This increase may be attributed to the decrease in moisture content of the samples during fermentation [25]. This may also be attributed to the fact that during fermentation of carbohydrate including cellulose, pectin, lignocellulose and starch are broken down by fermenting microorganisms thereby reducing the fibre content of such food [30]. The decrease in the carbohydrate content in FB (fermented 60 g cassava/40 g of plantain) could be due to the ability of fungi to hydrolyze starch into sugars, especially glucose that may be used by the isolates as a carbon source to synthesize biomass rich in protein for growth and metabolism [31,32].

Mineral composition of the blends increased with fermentation time. The significant increase in sodium, iron, calcium, potassium and zinc of fermented blends indicate that all these minerals were released from blend through the activities of microorganisms. Similar report was observed by Onoja and Obizoba [33]. This result is contrary to the findings of Adepoju et al. [34] who observed a decrease in mineral composition of plantain after fermentation except sodium; this could be that the minerals leached into the fermentation broth.

5. CONCLUSION

This result shows that fermentation had significant effect on the nutritional value of cassava and ripe plantain peel blend. Fermentation of agro allied waste products in the production of animal feed enhances the proximate and mineral composition of the feed which will bring about growth to animals. As a high energy and protein source like plantain peels, its inclusion in rat feed formulation would help to reduce the cost of feed. Also, the low moisture content observed in the fermented feed produced compared to the feed produced from raw cassava and plantain peel is expected to give a longer shelf life to the feed. Agricultural industries can make use of fermentation process to produce a well fortified and nourishing feed for animals from agricultural waste by products which will eradicate the inappropriate disposal of the waste causing environment pollution. This feed will also bring about less competition for survival of animals with human beings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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