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Enhancing the nutritional quality of fufu with a starter culture

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Abstract

This study investigates the nutritional enrichment of fufu, a staple African food, by controlling the fermentation of cassava root tuber using a starter culture. Lactic acid bacteria (LAB) were isolated from fermented cassava and analyzed for their technological properties. The physicochemical parameters, proximate and antinutrient content of the fufu samples were determined by standard analytical methods. Twelve LAB were identified as *Lactobacilli plantarum* (42%), *L. acidophilus* (25%), *L. fermentum* (17%), *L. brevis* (8%), and *L. mesenteroides* (8%). The LAB isolates produced lactic acid, diacetyl, and hydrogen peroxide ranging from 1.90-2.90, 1.30-2.10, and 1.10 -2.90 mg/mL respectively. *Lactobacillus plantarum* (FF8) was selected as a starter culture due to its exceptional ability to produce antimicrobial substances, leading to higher yields of lactic acid, diacetyl, and hydrogen peroxide, reducing the fermenting medium's pH. The pH changes in starter-induced fermented fufu (SIFF) and spontaneous fermented fufu (SFF) samples from 0 to 96 hours were 7.10 - 2.60 and 7.10 - 3.30, respectively, while the Total Titratable Acidity (TTA) increased from 0.71-1.79 and 0.28-0.51, respectively. Starter-induced fermented fufu (SIFF) has higher protein, fat, sodium, potassium, iron, zinc, phosphorus, and Vit. C, B1, and A content of 2.93, 0.23 (%) 596.4, 270.9, 8.93, 1.67, 296.67, 5.28, 0.24, and 0.31 (mg/100g) respectively, compared to spontaneous fermented fufu and a significant decrease in antinutrient content, such as cyanide, saponin, and phytates of 0.05, 0.16, and 0.06 (mg/100g), respectively. The study found that *L. plantarum* FF8 used as a starter culture, improves the nutritional value of fufu and reduces anti-nutrients, suggesting potential health benefits for consumers.

Keywords: Cassava; Fermentation; Fufu; Lactic acid Bacteria; Starter culture

1. Introduction

Cassava (*Manihot esculenta crantz*), a staple food crop in Nigeria, a starch-rich root that provides carbohydrates and energy for sub-Saharan Africa's population [1, 2,3]. It makes up 85% of the total weight and is highly carbohydrate-rich, and deficient in protein, riboflavin, thiamin, and niacin concentrations [4, 5]. Cassava is processed before consumption to detoxify, avoid post-harvest deterioration, reduce toxicity, improve product palatability, preserve and modify [6,7,8,9]. Fermentation is a suitable method for processing cassava roots. It enhances the safety, organoleptic, and nutritional quality of cassava-derived foods [10, 11].

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Cassava root is processed into various food items such as fufu, gari, and lafun. Fufu, a fermented product, provides 70% of Nigeria's daily calories [12]. Traditional processing involves peeling, washing, cutting, and steeping in water for 4-5 days. The softened root is then pulverized, sieved, and allowed to settle for decantation, resulting in raw fufu [13].

The fermentation of cassava for fufu production involves a dominant microbiota, including yeast species such as *Saccharomyces cerevisiae, Pichia scutulata*, and *Kluyveromyces marxianus*, as well as lactic acid bacteria (LAB) such as *Lactobacillus fermentum, Lactobacillus plantarum, Leuconostoc mesenteroides,* and spore formers such as Bacillus *cereus* [14, 15]. Lactic acid fermentation is the most effective technique for processing cassava into different products due to its ability to generate antimicrobolites, decrease antinutritional components, and enhance density [16, 17, 18, 19].

The controlled fermentation of cassava products is attributed to the use of microbial starter cultures, which contain a large number of viable microorganisms, primarily LAB, which often yields consistent products [20, 21, 22, 23]. Starters accelerate the fermentation process, antagonize undesirable microorganisms, and improve the final product's organoleptic and sensory attributes [24, 25, 26, 27, 28].

The development of a simple processing method for fufu can enhance its nutritional content and quality, thereby increasing consumer acceptability and ensuring its survival in the food chain. Therefore, this study aims to explore the potential nutritional enrichment of fufu using a starter culture isolated from the current study.

2. Materials and methods

2.1. Collections of samples

Fresh cassava roots were collected from Ajala village, Oluyole Local Government, Ibadan, Oyo state, and transported to the Microbiology and Biotechnology Laboratory of First Technical University, Ibadan for further processing.

2.2. Isolation of lactic acid bacteria (LAB)

Five kilograms (5 kg) of cassava root was washed, peeled, sliced into pieces, and steeped in distilled water for 72 hours at ambient temperature (28 ± 35 ^{o}C). The sample was then analyzed for microbiological analysis, added to sterile 0.1% peptone water (Oxoid, UK), and homogenized using a vortex machine (CM-101 Remi Cyclo Mixture, 1000 RPM) for 10 seconds. The homogenate was diluted to ten-fold serial dilution and then plated in sterile De Man Rogosa Sharpe (MRS) agar plates (Oxoid, UK). The colonies were incubated anaerobically in Gas Pak jars at 30°C for 48 hours. Representative colonies were randomly picked and purified, and pure cultures were grown on MRS agar slants and stored at 4°C for further use.

2.3. Physiological and biochemical characterization of lactic acid bacteria isolates

The isolates were tested for physiological and biochemical characteristics, including Gram staining, citrate, indole, oxidase, methyl red, Voges-Proskauer, and sugar fermentation tests by using standard procedure [29, 30, 31, 32], growth at different pH, 4% NaCl, starch hydrolysis casein hydrolysis and gelatin hydrolysis [33, 34]. Probable lactic acid bacteria were identified and confirmed using Bergey's Manual of Systematic Bacteriology [35] and Automated Biometric Identification System (ABIS online).

2.4. Technological properties of lactic acid bacteria isolates

2.6.1 Lactic acid production

The Association of Official Analytical Chemists (AOAC), [36] method was used to determine lactic acid produced by lactic acid bacteria isolates by titrating 25 mL of 24 h broth cultures with 0.1N NaOH until a pink color appeared, with phenolphthalein as an indicator. Each ml of 0.1N NaOH is equivalent to 90.08mg of lactic acid.

$$Lactic\ acid = Volume\ of\ NaOH\ (mL) \times Lactic\ acid\ equivalent\ (mg) \div Volume\ of\ the\ samples\ used\ (mL) \ldots\ldots$$
Equation 1

2.6.2 Diacetyl production

The Sanni [37] method was used to estimate the amount of diacetyl produced by lactic acid bacteria isolates. Twenty-five milliliters (25 mL) of MRS broth test isolates were aliquoted in 250 ml conical flasks, and residual titration was performed with 7.5 ml hydroxyl amine solution. The titration resulted in a green-yellow endpoint using bromophenol blue as an indicator. The equivalent factor of HCl to diacetyl is 21.52mg.

$$AK = (B - S)(100 - E) \div W \ldots\ldots\ldots Equation\ 2$$

AK = Percentage of diacetyl, B = ml of 0.1N HCl consumed in the titration of the sample,

E =Equivalent factor of 1 mL of 0.1N HCl to diacetyl=21.52mg, W= Volume of sample used, S= Volume of ml 0.1N HCl consumed in the titration of 7.5 mL Hydroxyl amine.

2.6.3 Hydrogen peroxide production

Twenty milliliters (20 mL) of 0.1 M H_2SO_4 were added to 25 mL of the MRS broth cultures of the test isolates (24 h). Titration was carried out with 0.1 N potassium permanganate. Each mL of 0.1 M H_2SO_4 is equivalent to 1.70 mg of Hydrogen peroxide and decolorization of the sample was regarded as an endpoint [36].

$$H2O2 = KMn04\ (mL) \times NKMnO4 \times ME\ \times 100 \div H2SO4\ (mL) \times\ Volume\ of\ sample\ used \ldots..Equation\ 3$$

2.5. Production of starter-induced fermented fufu (SIFF) and spontaneous fermentation fufu (SFF)

2.*5.1 Inoculum preparation*

The selected lactic acid bacteria as potential starter culture was inoculated in MRS broth and incubated anaerobically in Gas Pak jars (Gas Pak System, BBL) at 30 °C for 24 h. The culture was centrifuged at 3,000 rpm for 4 minutes, and the supernatant was discarded. The cell pellets were washed and resuspended in 0.9% normal saline solution, standardized to 0.1 absorbances at 600 nm for starter culture application.

2.5.2. Production of fufu samples

The study involved two fermentation methods for the production of fufu samples. The production of the SIFF involved the inoculation of 5 mL of the inoculum into 10 kg of blanched cassava, steeped in 15 liters of distilled water, and allowed to ferment anaerobically at a temperature of 37 °C ± 2 °C for 96 hours. In the production of SFF, involved washing, peeling, slicing, and steeping 10 kg of cassava roots in 15 liters distilled water for 72 hours without adding starter culture. The fermented cassava samples were pulverized, sieved, and sedimented for 12 hours, and the resulting water was then decanted. The fufu mash, obtained through two processing methods, were drained, dried in an oven at 55°C (Thermo Oven Lab-line Vacuum) for 72 hours, milled into powder using a VTCL Excella Grinder-1000W, packed in zip-lock bag, and stored at 4°C for proximate and antinutritional analyses.

2.7 Determination of pH and total titratable acidity

Fermented cassava samples were aseptically taken at 24-hour intervals for pH and TTA evaluation. A digital pH meter (HANNA INSTRUMENT 8021) was used to measure pH, while total titratable acidity (TTA) was assessed using AOAC methods [36]. Ten grams of the sample was titrated against 0.1M sodium hydroxide solution, resulting in a faint pink color endpoint (pH 8.3). One milliliter of 0.1M NaOH was equivalent to 9.008 mg of lactic acid [36].

$$TTA = Volume\ (mL)\ of\ NaOH\ \times Normality\ of\ NaOH\ \times Lactic\ acid\ equivalent \div Volume\ of\ samples\ uses \ldots\ldots\ldots..Equation\ 4$$

2.8 Determination of the proximate composition of the lafun samples

2.8.1 Determination of moisture content

The moisture content of the fufu samples were determined by drying clean crucibles in a hot air oven at 100°C for 1 hour, then cooling in a desiccator. Two grams of each sample were then weighed and dried at 100°C until a constant weight was obtained [38].

$$\%\ moisture\ content = W2 - W3\ \times 100\ \div W2 - W1 \ldots\ldots\ldots\ldots Equation\ 5$$

W1 = Initial weight of the empty crucible; W2 = weight of dish + sample before drying; W3 = weight of dish + sample after drying

2.8.2 Determination of fat

The Soxhlet extraction method was used to determine fat content of the fufu samples, following AOAC's guidelines [38]. A Soxhlet extractor with a reflux condenser and a 500 mL round bottom flask was used. Two grams of sample were

weighed into a labeled thimble, and 300 ml of petroleum ether was filled into the flask. The extractor thimble was sealed, refluxed for 6 hours, and collected. Petroleum ether was dried at 105 °C for 1 hour and oven-cooled before weighing.

$$\%\ Fat = Weight\ of\ fat\ \times 100\ \div Weight\ of\ sample\ \ldots\ldots Equation\ 6$$

2.8.3 Determination of crude protein

The micro-Kjeldahl method was used to determine protein percentage in the fufu samples. A gram of each sample was weighed into a Kjeldahl flask, and 2.5 g of anhydrous Na_2S0_4, 0.5 g of $CUSO_4$, and 5 mL concentrated H_2S0_4 were added. The flask was heated in a flame chamber, then transferred to a volumetric flask. The digest was distilled, mixed with 5 mL boric acid indicator and 3 drops methyl red, and titrated against 0.01 N HC1, resulting in a purple-colored endpoint. [38]. The percentage protein was calculated using the following expression.

$$\%\ Nitrogen = T \times 14.01\ \times 0.01 \times 20 \times 100\ \div 1.0\ \times 100\ \ldots\ldots Equation\ 7$$

T = Titer value; 1.0 g = Weight of the sample 20 = Dilution factor (i.e. from 10,015) 0.01 = Normality of HCl 14.01 = Atomic mass of nitrogen

2.8.4 Determination of total ash

The AOAC procedure [38] was used to determine ash content in well-blended fufu samples. Two grams of each sample were weighed, ignited, and cooled before being transferred to a muffle furnace at 550°C. After 8 hours, the sample was moistened, dried, and re-ashed at 550 °C for an additional hour. The percentage of ash was calculated using the following expression.

$$\%\ Ash = Weight\ of\ Ash\ \times 100\ \div Weight\ of\ sample\ used\ \ldots\ldots Equation\ 8$$

2.8.5 Determination of crude fiber

The AOAC method [38] was used to determine crude fiber by boiling two grams of sample in 200 mL 1.25% H_2SO_4 for 30 minutes, filtering through cloth, washing with water, returning to 200 mL NaOH, washing with 1% HCl, draining, and drying. The residue was then transferred to a silica ash crucible, dried, and cooled. Percent crude fiber was calculated using this method.

$$\%\ Crude\ fiber = Loss\ in\ weight\ on\ ignition\ \times 100\ \div Weight\ of\ the\ sample\ \ldots\ldots Equation\ 9$$

2.8.6 Determination of carbohydrate

The total carbohydrate content was estimated as the difference between 100 and the total sum of moisture, fat, protein, crude fiber, and ash as described by AOAC [38].

2.8.7 Determination of vitamins and mineral

The study analyzed riboflavin, thiamine, niacin, and ascorbic acid using standard procedures and mineral analysis methods [38]. Samples were ashed (Lenton muffle furnace AF11/6) at 550 °C, boiled with 10 mL 20 % HCl, and filtered. The minerals sodium and potassium were determined using a flame emission photometer, with NaCl and KCl as standards (AOAC, 2005). Phosphorus was determined calorimetrically using the spectronic 20 with KH_2PO_4 as the standard. All values were expressed in mg/100 g.

2.8.8 Determination of antinutrients

The rapid test method of AOAC [39] was used to determine the anti-nutrients including phytates, saponin and hydrogen cyanide in the fufu samples.

2.9 Statistical Analysis

Results were presented as means with a standard deviation of triplicate values and were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (Free SPSS version 16.0). Significant differences between means were determined at 95% confidence limit ($p< 0.05$) and were compared using Duncan multiple range test.

3 Results

Twelve (12) lactic acid bacteria (LAB) were identified as *L. plantarum* (42%), *L acidophilus* (25%), *L. fermentum* (17%), *L. brevis* (8%), and *L. mesenteroides* (8%) (Figure 1). The LAB isolates produced lactic acid, diacetyl, and hydrogen peroxide ranging from 1.90 -2.90, 1.30 -2.10, and 1.10 -2.90 mg/mL respectively (Table 1). Table 2 shows the optical density of LAB isolates at pH 3, 7, and 12, and growth at 4% NaCl at 600nm. *L. plantarum* (FF8) grew better at extreme pH values 3 and 12 and 4% NaCl of 0.39, 1.08, and 0.75 respectively.

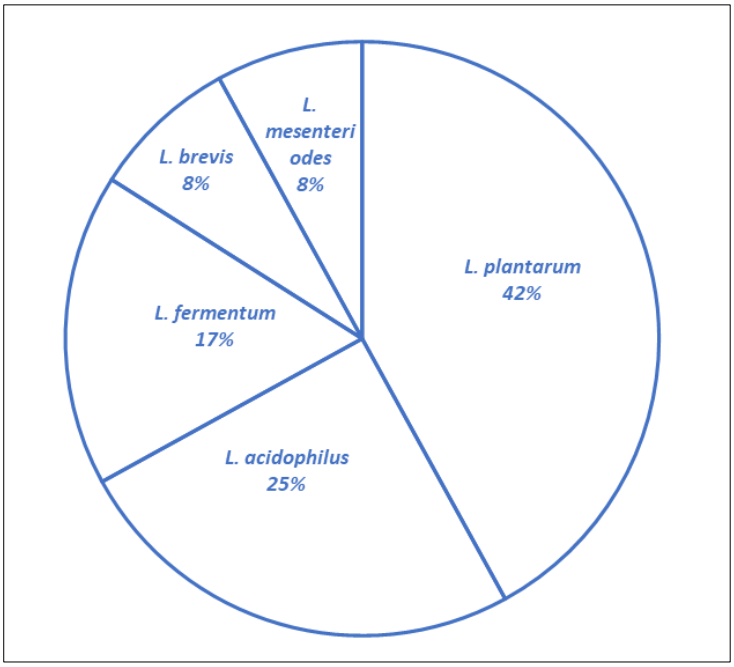

Figure 1 Percentage occurrence of the LAB isolates

Table 1 Production of antimicrobial compounds by the LAB isolates (mg/mL)

Lab isolates	Lactic acid	Diacetyl	Hydrogen peroxide
L. acidophilus FF1	2.60±0.20^{b}	2.10±0.20^{b}	1.50±0.20^{a}
L. plantarum FF2	2.30±0.20^{b}	1.70±0.20^{a}	1.30±0.20^{a}
L. mesenteroides FF3	2.60±0.20^{b}	1.60±0.20^{a}	1.10±0.20^{a}
L. brevis FF4	1.80±0.20^{a}	1.90±0.20^{a}	1.50±0.20^{a}
L. acidophilus FF5	2.60±0.20^{b}	1.80±0.20^{a}	1.50±0.20^{a}
L. plantarum FF6	2.40±0.20^{b}	1.80±0.20^{a}	1.10±0.20^{a}
L. acidophilus FF7	2.40±0.20^{b}	1.60±0.20^{a}	1.50±0.20^{a}
L. plantarum FF8	2.90±0.20^{b}	2.60±0.20^{b}	2.90±0.20^{b}
L. fermentum FF9	2.00±0.20^{b}	1.30±0.20^{a}	1.30±0.20^{a}
L. plantarum FF10	1.90±0.20^{a}	1.50±0.20^{a}	1.30±0.20^{a}
L. fermentum FF11	2.30±0.20^{b}	1.6±0.20^{a}	1.60±0.20^{a}
L. plantarum FF12	2.40±0.20^{b}	1.50±0.20^{a}	1.70±0.20^{a}

Values are presented as Means ± Standard Deviation where n = 3. Values with different superscript letter within each column are significantly different ($p< 0.05$).

Table 2 Optical density at 600nm of the LAB isolates of different pH and 4% NaCl

Lab isolates	pH 3	pH 7	pH 12	4% NaCl
L. acidophilus FF1	0.30±0.0020^{c}	0.58±0.0020^{b}	0.27±0.0020^{a}	0.30±0.0020^{b}
L. plantarum FF2	0.32±0.0020^{c}	0.53±0.0020^{b}	0.92±0.0020^{d}	0.36±0.0020^{b}
L. mesenteroides FF3	0.25±0.0118^{b}	0.30±0.0020^{a}	0.67±0.0020^{c}	0.28±0.0020^{a}
L. brevis FF4	0.05±0.0020^{a}	0.56±0.0190^{b}	0.94±0.0020^{d}	0.53±0.0020c
L. acidophilus FF5	0.32±0.0020^{c}	0.59±0.0230^{b}	0.68±0.0020^{b}	0.32±0.0020^{b}
L. plantarum FF6	0.36±0.2310^{c}	0.31±0.0014a	0.80±0.0020^{d}	0.38±0.0116^{b}
L. acidophilus FF7	0.28±0.0020^{b}	0.58±0.0020^{b}	0.87±0.0020^{d}	0.30±0.0020^{b}
L. plantarum FF8	0.39±0.0020^{c}	0.72±0.0020^{d}	1.08±0.0012^{e}	0.75±0.0020^{c}
L. fermentum FF9	0.27±0.0020^{b}	0.63±0.0020^{c}	0.57±0.0020^{b}	0.30±0.0020^{b}
L. plantarum FF10	0.29±0.0020b	0.59±0.0020^{b}	0.95±0.0020^{a}	0.32±0.0020^{b}
L. fermentum FF11	0.35±0.0020^{c}	0.59±0.0020^{b}	0.77±0.0020^{c}	0.65±0.0594^{c}
L. plantarum FF12	0.22±0.0020^{b}	0.61±0.0020^{c}	0.58±0.0020^{b}	0.32±0.0020^{b}

Values are presented as Means ± Standard Deviation where n = 3. Values with different superscript letter within each column are significantly different ($p < 0.05$).

The pH changes in starter induced fermented fufu (SIFF) and spontaneous fermented fufu (SFF) samples from 0 to 96 hours were 7.10 - 2.60 and 7.10 - 3.30, respectively. The Total Titratable Acidity (TTA) increase was observed in starter induced fermented fufu (SIFF) and spontaneous fermented fufu (SFF) samples, ranging from 0.71-1.79 and 0.28-0.51, respectively (Table 3)

Table 3 pH and TTA of *lafun* samples

	SIFF		SFF	
	PH	**TTA (g/L)**	**pH**	**TTA (g/L)**
0 hour	7.1±0.10	0.71±0.01	7.1±0.10	0.28±0.01
24 hours	4.7±0.10	0.91±0.01	5.7±0.10	0.36±0.01
48 hours	4.1±0.10	1.25±0.01	4.5±0.10	0.41±0.01
72 hours	4.6±0.10	1.51±0.01	3.8±0.10	0.47±0.01
96 hours	2.6±0.10	1.79±0.01	3.3±0.10	0.51±0.01

Values are the Means ± Standard Deviation where n = 3; SIFF: Starter Induced Fermented Fufu; SFF: Spontaneous Fermented Fufu

The study compared the proximate compositions of starter-induced fermented fufu (SIFF) and spontaneously fermented fufu (SFF) samples. SIFF had significantly higher protein, fat, sodium, potassium, iron, zinc, phosphorus, Vit. C, B1, and A of 2.93, 0.23 (%) 596.4, 270.9, 8.93, 1.67, 296.67, 5.28, 0.24, and 0.31 (mg/100g) respectively, while SFF had higher moisture content, carbohydrate, crude fiber, and ash content of 8.80, 85.70, 3.47 and 4.8 (%) respectively (Table 4). Additionally, SIFF showed a significant decrease in antinutrient content, such as cyanide content, saponin, and phytates 0.05, 0.16 and 0.06 (mg/g), compared to SFF (Table 5).

Table 4 Proximate composition of fufu samples

Parameters	**SIFF**	**SFF**
Protein %	4.93±0.01^{b}	2.90±0.10^{a}
Moisture%	5.67±0.01^{b}	8.80±0.01^{a}
CHO %	80.36±0.01^{a}	85.70±0.10^{b}
Fiber %	2.87±0.01^{a}	3.47±0.01^{b}
Ash %	2.67±0.01^{a}	4.87±0.01^{b}
Fat %	0.23±0.01^{a}	0.12±0.01^{b}
Sodium (mg/100g)	514.64±0.10^{b}	295.94±0.10^{a}
Potassium (mg/100g)	270.90±0.10^{b}	83.92±0.01^{a}
Iron (mg/100g)	8.93±0.01^{b}	3.33±0.10^{a}
Zinc (mg/100g)	1.67±0.01^{a}	1.33±0.01^{a}
Phosphorus (mg/100g)	296.67±0.01^{b}	181.67 ±0.10^{a}
Vit. C (mg/100g)	5.28±0.01^{b}	3.62±0.01^{a}
Vit. B1 (mg/100g)	0.24±0.01^{b}	0.16±0.01^{a}
Vit. A (mg/100g)	0.31±0.01^{b}	0.25±0.01^{a}

Values are presented as Means ± Standard Deviation where n = 3. Values with different superscript letter within each column are significantly different ($p< 0.05$). SIFF: Starter Induced Fermented Fufu; SFF: Spontaneous Fermented Fufu.

Table 5 Antinutrient content of the lafun samples

Samples	**Cyanide** (mg/100g)	**Saponin** (mg/100g)	**Phytates** (mg/100g)
SIFF	0.05±0.01a	0.16±0.01a	0.06±0.01a
SFF	0.15±0.01b	0.22±0.01b	0.22±0.01b
RC	0.98±0.10c	-	-

Values are presented as Means ± Standard Deviation where n = 3. Values with different superscript letter within each column are significantly different ($p< 0.05$). SIFF: Starter Induced Fermented Fufu; SFF: Spontaneous Fermented Fufu. RC: Raw cassava

4 Discussion

The study found that *L. plantarum* isolates are the most prevalent possibly due to their simpler nutritional needs, potentially offering a metabolic advantage over other *Lactobacillus* spp. [40, 41, 42]. Studies by McDonald *et al.* [43] and Makimattila *et al.* [41] have identified *L. plantarum* as the predominant bacteria in natural and spontaneous lactic acid fermentation of cassava roots which aligns with the findings of Padonou *et al.* [41]. The lactic acid bacteria species identified in this study have been previously documented in cassava fermentation across a range of fermented food items [44, 45, 6,46].

Lactobacillus plantarum (FF8) exhibited the higher yield of lactic acid, diacetyl, and hydrogen peroxide, which resulted in a reduction of the fermenting medium's pH and the formation of inhibitory bioactive compounds possessing antimicrobial properties. These compounds hinder the proliferation and development of pathogenic organisms in fermented foods, which can be generated at different concentrations by distinct LAB strains [47,48]. The growth of LAB isolates at pH 3 aligns with Cotter and Hill's work [49], which suggests that this growth is due to the relative ATPase activities of microorganisms at different pH levels. This ability enhances the probiotic benefits of LAB, allowing them to survive in stomachs with low pH levels as low as 1.5. Additionally, LAB inhibits pathogenic organism growth in fermented foods [48]. *Lactobacillus plantarum* (FF8) was selected as a starter for the fermentation of starter-induced

fufu, due to its exceptional ability to produced antimicrobial properties in higher amount and outstanding performance in various tests.

The pH of cassava roots decreases during fermentation due to the production of organic acids by lactic acid bacteria. This reduction is consistent with previous studies, with a decrease observed with increasing fermentation time [46]. The production of lactic acid reduces the pH of the fermenting medium and produces inhibitory bioactive compounds such as diacetyl and hydrogen peroxide, responsible for most antimicrobial activity [50].

The increased crude protein content in the starter-induced fermented fufu (SIFF) may be attributed to the higher production of organic acids by *L. plantarum* FF8. These organic acids facilitate the growth and multiplication of single-cell proteins [51]. Additionally, the secretion of extracellular enzymes by *L. plantarum* FF8 may also contribute to the higher crude protein content [52]. The cassava root flour process, as described by Udoro *et al.* [53], effectively reduces moisture through drying, thereby enhancing resistance to microbial infestation, thereby extending the shelf life of the flour during storage. The crude fibre content in fufu samples, as determined by SIFF (2.87%) and SFF (3.47%), aligns with Afoakwa *et al.* [54] and Gil and Buitrago [55] recommendations. Consuming adequate dietary fibre can reduce the risk of diseases such as constipation, obesity, coronary heart diseases, and colon cancer, as noted by Dahl and Stewart [56]. The study found that SIFF has a reduced carbohydrate content compared to SFF of 80.6% and 85.5% respectively. The carbohydrate contents of both samples are suitable for starch production, and these values align with the reports of Alamu *et al.* [57]. The study found that starter-induced fermented fufu (SIFF) had significantly higher vitamin C, B1, and A content compared to spontaneous fermented fufu (SFF) due to the inoculation of *L. plantarum* FF8 that enhances nutrient production during fermentation. Vitamins play a role as antioxidants, helping to combat free radicals [58]. The mineral content in SIFF may increase due to the decrease in phytates during fermentation, possibly due to the loss of dry matter [59]. Additionally, fermentation increases the bioavailability of calcium, phosphorus, and iron due to the degradation of oxalates and phytates, which complex with minerals [60], indicating that *L. plantarum* FF8 has a unique capacity to enrich fufu samples.

Fermentation can decrease the cyanide content of cassava, as demonstrated by Niguse *et al.* [61]. *Lactobacillus plantarum* FF8 significantly reduced the free cyanide level from 0.98 to 0.05mg/g after 96 hours of fermentation. This decrease is due to the linamarase enzyme produced by inoculated microorganisms, which catalyzes the hydrolysis of linamarin and conversion of cyanogenic glycosides to HCN. This process prevents acute toxicity and promotes cyanide detoxification [62].

5. Conclusion

The study found that *L. plantarum* FF8 used as a starter culture, improves the nutritional value of fufu and reduces anti-nutrients, suggesting potential health benefits for consumers. Further research is needed to explore the long-term effects on gut health and overall well-being of fufu made with *L. plantarum* FF8.

Compliance with ethical standards

Acknowledgement

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Disclosure of conflict of interest

The authors declare no conflict of interest

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