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THE EFFECT OF DIFFERENT FERMENTATION TECHNIQUES ON THE NUTRITIONAL QUALITY OF THE CASSAVA PRODUCT (FUFU)

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ABSTRACT

The nutritional qualities of fufu produced from traditional, brine and backslopping fermentation techniques were evaluated. The cassava roots were steeped in water (1:4 kg/L) for 96 h for the production of traditional-fermented sample while fermented cassava liquor (10%w/v) was used to initiate fermentation in the backslopping technique. Two-staged method that involved fermentation and grating was employed for the production of brine-fermented sample. The resultant "wet fufu" samples were dried at 65C in a cabinet dryer and mechanically milled into flour. The hydrogen cyanide level, proximate composition, functional properties, mineral contents and the sensory evaluation of the flour samples were assessed. Lactic acid bacteria populations comprised more than 95% of the total viable bacteria and remained prominent through the fermentations, while the number of coliforms and moulds declined as the fermentation progressed. *Lactobacillus plantarum, L. buchnerii, L. casei* were implicated in the brine fermentation. The hydrogen cyanide observed after fermentation and processing were 15.67 ± 0.63 mg/kg, 13.29 ± 0.68 mg/kg and 12.07 ± 0.32 mg/kg for the traditional, brine and backslopping-fermented samples, respectively. Lowest moisture content (10.61 ± 0.15%) was recorded in backslopping-fermented sample and highest (12.69 ± 0.34%) in traditional-fermented sample. The ash and carbohydrate contents range from 0.76 ± 0.23% to 0.92 ± 0.27% and 82.57 ± 0.56% to 84.03 ± 0.58%, respectively. Higher protein contents were observed in brine (2.25 ± 0.19%) and backslopping (2.32 ± 0.13%) fermentations while the lowest crude fiber content (0.84 ± 0.43%) was obtained in the brine-fermented sample. The results of the functional properties show similar trend. Brine and backslopping fermentation techniques offer lighter "fufu" flours and dough as indicated by the lower swelling index (3.16 ± 0.09 g/g and 2.66 ± 0.18 g/g, respectively) and bulk density (0.65 ± 0.03 g/mL and 0.57 ± 0.03 g/mL, respectively). The traditional-fermented sample had the highest water absorption capacity (4.89 ± 0.06%). Brine fermentation significantly ($P < 0.05$) increased the Ca (0.235 ± 0.004 mg/kg), Na (0.555 ± 0.055 mg/kg) and K (0.504 ± 0.009 mg/kg) contents of fufu flour than the traditional fermentation which were 0.162 ± 0.003 mg/kg, 0.0097 ± 0.011 mg/kg and 0.151 ± 0.003 mg/kg respective. Sensory scores showed that production of fufu using brine fermentation is more preferred than traditional fermentation.

PRACTICAL APPLICATIONS

In recent times, attention has been drawn to the enrichment of protein in cassava products by various methods. However, brine and backslopping fermentation techniques of cassava roots are valuable biotechnological approach in achieving this. Because cassava has been recognized as a suitable crop for micronutrient intervention in Africa, its planting and processing into various products like "fufu" flour should be encouraged. Fabrication of cheap local dryer, which can hygienically convert the "fufu wet cake" into flours is strongly recommended and should be made available in the rural areas where larger population of the consumers of this cassava product are located.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a tropical root crop that serves as a food security and income generation for many millions of people in the developing world (Scott and Rosegrant 2002). The cyanogenic glucosides content in the cassava roots vary according to the studied varieties (Gomez *et al.* 1984; Agbor-egbe *et al.* 1995). In 1999, Nigeria produced 33 million tonnes making it the world's largest producer (Sobowale *et al.* 2007). Over 70% of production in Nigeria is consumed locally (Daramola and Osanyinlusi 2006; Oyewole and Biola 2006). Despite their higher cyanide content, the bitter cassava varieties are more predominantly utilized (RMRDC 2004). The reliance on cassava as a food source and the resulting exposure to the goitrogenic effects of thiocyanate has been responsible for the endemic goiters seen in the Akoko area of South Western Nigeria (Akindahunsi *et al.* 1998). It is a problem particularly in the region where cassava is the major source of calories (Oke 1980; Umoh *et al.* 1985; Balagopalan *et al.* 1988).

Fermentation is an important unit operation for the processing of cassava for human consumption in Africa (Mahingu *et al.* 1987). Many food products made from cassava in Africa are product of fermentation (Oyewole and Odunfa 1992). Common fermented cassava products of West Africa include "Gari," "fufu" and "Lafun," among others (Oyewole 1991). Among the fermented cassava products, "fufu" is unique because in the traditional processing, the product is not subjected to any other processing after fermentation before cooking (Sobowale *et al.* 2007). During fermentation of "fufu" lactic acid bacteria (LAB), yeast and other bacteria contribute significantly to starch breakdown, acidification and flavor development (Oyewole 1991). Among the factors limiting increased production and consumer choice of cassava "fufu" include its characteristics inherent foul odor resulting from the uncontrolled and unhygienic fermentation storage techniques (RMRDC 2004). Brining is the application of salt in the fermentation of foods such as fish, vegetable and fruits. It has been used to control microbial proliferation and to inhibit the growth of putrefactive organisms (Rose 1982). This research is aimed at studying the impact of different fermentation techniques such as backslopping and brine fermentations on the quality of "fufu" and the potential of replacing the common spontaneous fermentation with other techniques during "fufu" production. The use of brine and accelerated batch fermentation techniques has not been reported in "fufu" processing and production.

MATERIALS AND METHODS

Source of Raw Materials

The raw material used in this work was the bitter cassava variety (*Manihot utilisim*) harvested from a local farm in the Federal Institute of Industrial Research Oshodi (FIIRO), Lagos, Nigeria, 10–12 months after planting and processed immediately after harvesting. Fermentation experiments for each technique studied were prepared in duplicate.

Production of Fermented "fufu" Flours

Spontaneous, backslopping and brine (4%) were the three fermentation techniques employed during this research work for the production of *fufu* flours from bitter cassava variety (*M. utilisima*). After sorting, peeling, cutting (cubes of 10 g each) and washing, the cassava roots were divided into three portions for processing. A one-stage method of "fufu" production described by Oyewole (1991) (Fig. 1, path A) was slightly modified and used for the production of the spontaneous and the accelerated batch fermented "fufu" flours. The cassava roots were steeped in water (in ratio 1:4 kg/L) for 96 h. Natural microflora from the fermenting substrates was allowed to initiate the spontaneous fermentation while fermented cassava liquor (10%w/v) that has been fermented for 96 h traditionally was used as a starter culture for the backslopping technique. The two-staged method that involved fermentation and grating was employed for the production of brine-fermented "fufu" flour sample. The details are shown in Fig. 1.

Microbiological Analysis

Daily (24 h) changes in the microbial population (cfu/mL) of the total viable bacteria, LAB, coliforms, yeast and fungi were determined using standard plate agar (Oxoid, Basingstoke, Hampshire, UK), deMan Rogosa and Sharpe (MRS) agar (Oxoid), MacConkey agar (Oxoid) and malt extract agar (Oxoid), respectively. Samples were enumerated by using appropriate serial dilution and spread plate methods.

The fungal plates were incubated at 25C for 2–5 days while the bacterial cultures were incubated at temperatures ranging between 30 and 35C for 24–48 h. MRS agar was incubated under anaerobic conditions using a H_2/CO_2 generating kit (Oxoid). Isolation was also carried out at 144 h of the fermentation to determine the occurrence of spoilage microorganisms in cassava fermentation. The purified cultures of bacteria obtained were classified and identified using the procedures described by Collins *et al.* (1989), Olutiola *et al.* (1991) and Holt *et al.* (1994). The fungal isolates were identified by Barnett and Hunter (1972).

Chemical Analysis

The pH and Total Titratable Acidity Ten gram (10 g) of the fermenting cassava roots was homogenized with 90 mL of the fermenting liquor and then 10 mL of the mixture was transferred into 90 mL sterile distilled water. The pH of the resulting suspension was measure using an Orion pH meter

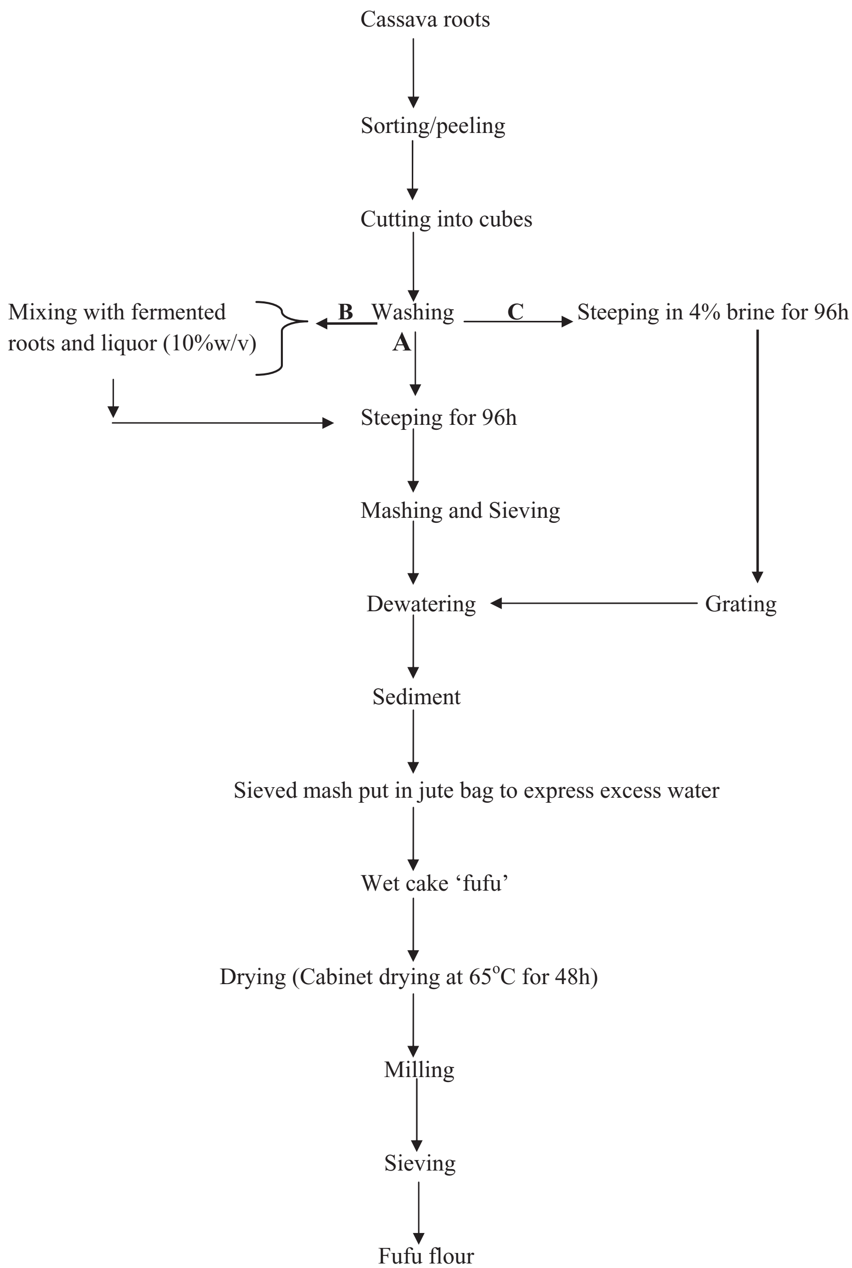

FIG. 1. SEQUENCE OF OPERATIONS EMPLOYED IN THE PROCESSING OF THE FUFU FLOUR SAMPLES
(A) Showed the production of traditionally fermented fufu flour. (B) Showed the production of backslopping-fermented fufu flour. (C) Showed the production of brine-fermented fufu flour.

(model 310, Orion Research Inc., Beverly, MA) equipped with a glass electrode. Triplicates determination were made in all cases. The pH meter was calibrated with buffer solutions of pH 7.0 and 4.0.

The total titratable acidity (TTA) was determined by titrating 20 mL of the same sample against 0.1 M sodium hydroxide (Antony and Chandra 1997).

Hydrogen Cyanide Content The hydrogen cyanide (HCN) content of the intermediate and the final product were determined using the AOAC (1990).

Proximate Composition The moisture, fiber, protein ($N \times 6.25$), fat and ash contents of the flour samples were determined using the procedure of AOAC (1995).

Mineral Elements The mineral elements were determined by the procedure of AOAC (1990). Calcium and magnesium were determined using Perkin-Elmer atomic absorption spectrophotometer (Waltham, MA). Potassium and sodium were determined by using the flame photometer, while phosphorus was determined by calorimetric method using ammonia molybdate.

Functional Properties The bulk density (BD) of the flour samples was determined using the procedure of Narayana and Narasinga (1984). The procedures of Sathe *et al*. (1982) and Sosulski (1962) were combined to determine the water absorption capacity (WAC) while the process of Tester and Morrison (1990) was employed for the determination of swelling index (SI).

Sensory Evaluation Sensory evaluation of the flour samples was carried out by a 10-man trained panel of people familiar with the product using scoring technique and was asked to assess the qualities of the fermented samples. The parameters assessed were color or appearance, aroma (level of presence of inherent odor), smoothness or texture in the mouth, taste, and overall acceptability. A 7-point hedonic scale was used for the evaluation with "G" having excellent acceptability for the attribute and "A" indicating high characteristics difference from the normal or very low acceptability. The final scores represent the number of panelists that selected each option.

Statistical Analysis Data obtained were subjected to analysis of variance using the Statistical Package for the Social Sciences (SPSS) 17.0 (IBM SPSS Inc., Chicago, IL) and mean separation was carried out with Duncan's new multiple range test to determine significant differences at 5% probability.

RESULTS AND DISCUSSION

A total of 21 microorganisms were identified from the three fermentation techniques employed for the production of *fufu* flour samples. The coliforms were *Enterococcus* sp. and *Enterococcus aerogenes*, the total viable bacteria were; *Klebsiella aerogenes*, *Bacillus subtilis, B. coagulans*, *K. liquefasciens*, *Corynebacterium* sp, *B. megaterium* and *B. licheniformis* while the LAB isolated include *Lactobacillus acidophilus*, *L. plantarum*, *L. brevis*, *L. buchnerii*, *L. cellobiosus*, *Pediococcus* sp. and *L. casei*. The yeast isolates were *Saccharomyces cerevisiae*, *Candida tropicalis* and *C. valida* while the fungi isolated were *Geotricum klebahnii* and *Aspergillus niger*.

The microbial growth during the spontaneous, accelerated batch and brine fermentation of cassava roots for *fufu* production are illustrated in Fig. 2a–c. LAB exhibited an increase in microbial counts in the three fermentation techniques studied. Among the seven LAB isolated from the backslopping fermentation, the occurrence of *L. plantarum* was low at 0 h and was dominant at the 96 h while *L. buchnerii* was only observed at 0 and 24 h of the fermentation periods. *Pediococcus* spp. only occurred at 72 and 96 h of the fermentation. The occurrence and succession of LAB during the backslopping fermentation is shown in Table 1. In the

TABLE 1. CHANGES IN HYDROGEN CYANIDE CONTENTS OF CASSAVA ROOTS DURING "FUFU" PRODUCTION BY TRADITIONAL, BRINE AND BACKSLOPPING FERMENTATION TECHNIQUES

Samples	"Wet Cake fufu"	Fufu flour
TFS	21.38 ± 0.75^c	15.67 ± 0.63^b
BFS	17.95 ± 0.59^c	13.29 ± 0.68^b
BSFS	16.87 ± 0.31^c	12.07 ± 0.32^b

Values are means ± standard deviation of triplicate determinations.
Means with the same superscript in the same column are not significantly different ($P \leq 0.05$).
BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

brine (4%) fermentation technique, *L. plantarum*, *L. buchnerii*, *L. casei* and *Pediococcus* spp. were isolated while the growth of *L. acidophilus*, *L. brevis* and *L. cellobiosus* were not supported.

S. cerevisiae was the first yeast observed at 0 h in the backslopping fermentation and at 48 h in the spontaneous fermentation and remain dominant throughout the fermentation periods. *C. valida* and *C. tropicalis* were not detected until 72 h in the brine fermentation. *S. cerevisiae* and *C. tropicalis* were the only surviving yeast in the spontaneous and backslopping fermentation techniques after 96 h and thrived even till 144 h. *G. klebhanii* and *A. niger* were the two molds isolated at 0 h in backslopping and spontaneous fermentations. The coliforms were observed at 0 h in the backslopping fermentation but were not detected until 24 h in the brine and spontaneous fermentations. They were eliminated within the first 24 h in backslopping fermentation together with molds after their initial increase, but *G. klebhanii* thrived up to 48 h in spontaneous fermentation after which it was eliminated. The brine fermentation technique did not support the growth of both the coliforms and the molds.

On the basis of changes in pH and TTA, the three fermentation techniques studied showed high similarity. The pH changes during the fermentation process are illustrated in Fig. 3. In spontaneous and backslopping fermentations the pH level decreased gradually from 6.11 to 3.85 and from 5.94 to 3.81 after 96 h of fermentation, respectively. Also, in the brine fermentation the pH decreased from 6.15 at 0 h to 3.89 at 96 h of fermentation.

Increase in the total TTA was observed throughout the fermentation process (Fig. 4). The total TTA of the samples increased from 0.083, 0.090 and 0.107 lactic acid/100 g at the onset (0 h) of the fermentation to 0.233, 0.272 and 0.371 after 96 h of spontaneous, brine and backslopping fermentations, respectively. Increase in the acidity was observed to be highest in the backslopping-fermented sample.

Table 1 indicated a progressive decrease in the HCN content of the raw cassava roots after fermentation

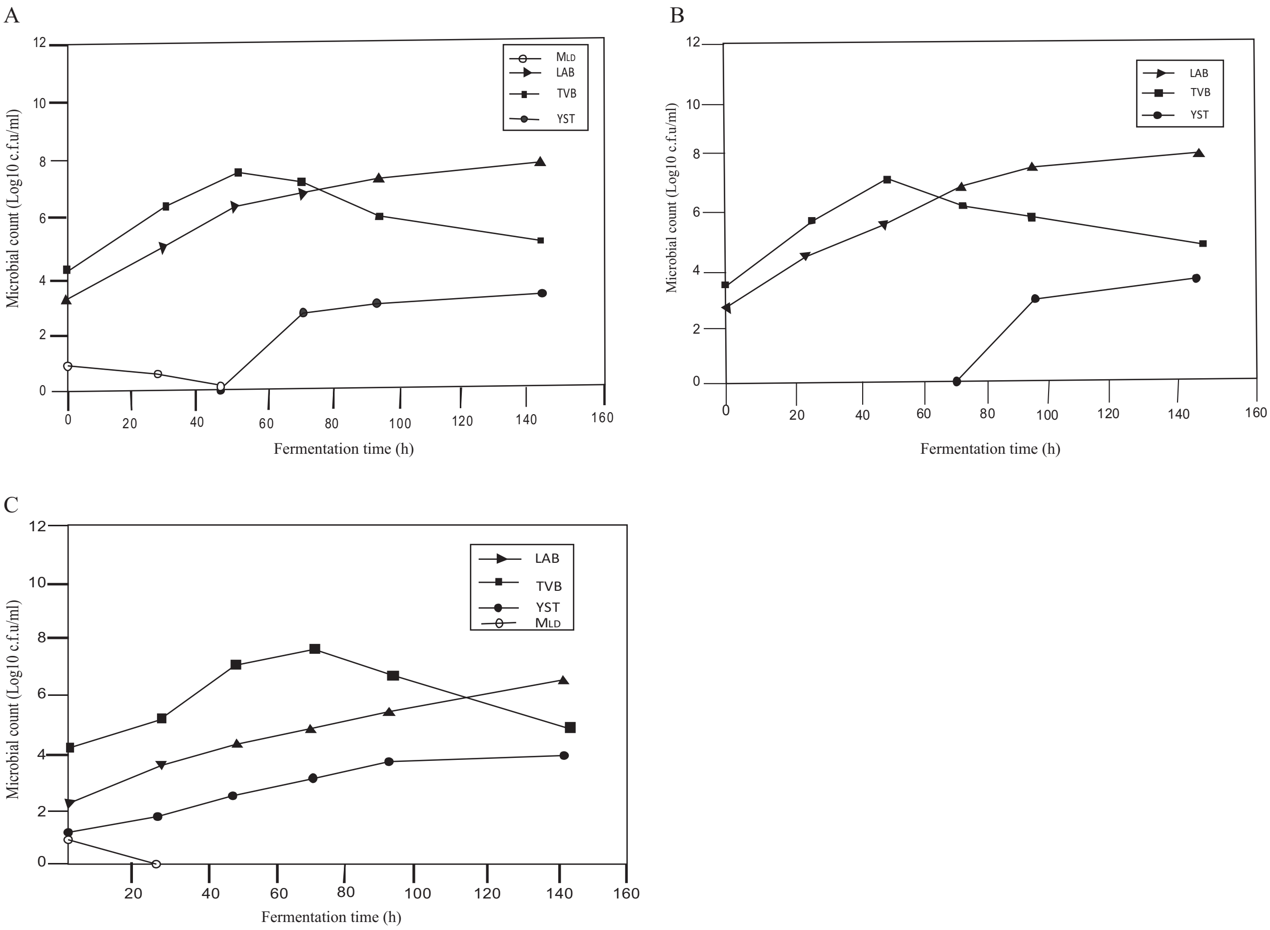

FIG. 2. (A) MICROBIAL COUNTS DURING THE SPONTANEOUS (TRADITIONAL) FERMENTATION OF CASSAVA ROOTS FOR "FUFU" PRODUCTION. (B) MICROBIAL COUNTS DURING THE BRINE FERMENTATION OF CASSAVA ROOTS FOR "FUFU" PRODUCTION. (C) MICROBIAL COUNTS DURING THE BACKSLOPPING (ACCELERATED BATCH) FERMENTATION OF CASSAVA ROOTS FOR "FUFU" PRODUCTION
LAB, lactic acid bacteria; TVB, total viable bacteria; YST, yeasts; MLD, molds.

and processing to the "wet cake *fufu*" (the intermediate product) and the *fufu* flour (the final product). Reduction in the HCN content from 88.59 mg/kg (raw tubers) to 15.67, 13.29 and 12.07 mg/kg were observed in spontaneous, brine and backslopping-fermented samples, respectively, after processing to "fufu" flours. Highest percentage reduction (86.38%) in HCN was observed in backslopping-fermented sample.

Table 2 shows the proximate composition of the three fermented "fufu" flour samples. Statistical analysis showed significant differences ($P < 0.05$) between the means of the variables estimated. The brine and backslopping fermentation techniques increased the crude protein, fat and carbohydrate contents of "fufu" flour than the spontaneous fermentation technique. There was no significant difference ($P < 0.05$) between the crude fiber and ash contents of the spontaneous and backslopping-fermented samples.

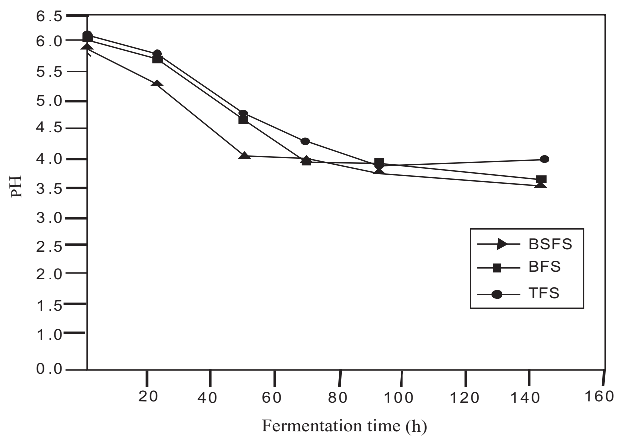

FIG. 3. THE pH CHANGES DURING THE FERMENTATION OF CASSAVA ROOTS FOR "FUFU" PRODUCTION
BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

TABLE 2. PROXIMATE COMPOSITIONS (%) OF TRADITIONALLY, BRINE AND BACKSLOPPING-FERMENTED "FUFU" FLOUR SAMPLES

Samples	Ash content (%)	Moisture content (%)	Crude fiber (%)	Crude protein (%)	Fat content (%)	Carbohydrate content (%)
TFS	0.76 ± 0.23^b	12.69 ± 0.34^c	1.23 ± 0.44^b	1.87 ± 0.16^b	0.88 ± 0.05^b	82.57 ± 0.56^a
BFS	0.92 ± 0.27^a	10.74 ± 0.28^a	0.84 ± 0.43^a	2.25 ± 0.19^a	1.22 ± 0.16^a	84.03 ± 0.58^b
BSFS	0.78 ± 0.08^b	10.61 ± 0.15^b	1.12 ± 0.12^b	2.32 ± 0.13^a	1.38 ± 0.11^c	83.79 ± 0.29^b

Values are means ± standard deviation of triplicate determinations.
Means with the same superscript in the same column are not significantly different ($P \leq 0.05$).
BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

TABLE 3. THE FUNCTIONAL PROPERTIES OF THE TRADITIONAL, BRINE AND BACKSLOPPING-FERMENTED "FUFU" FLOUR SAMPLES

Samples	Swelling index (g/g)	Bulk density (g/mL)	Water absorption capacity (%)
TFS	3.32 ± 0.14^b	0.69 ± 0.03^b	4.89 ± 0.06^c
BFS	3.16 ± 0.09^b	0.65 ± 0.03^b	4.32 ± 0.10^b
BSFS	2.66 ± 0.18^a	0.57 ± 0.03^a	3.40 ± 0.10^a

Values are means ± standard deviation of triplicate determinations.
Means with the same superscript in the same column are not significantly different ($P \leq 0.05$).
BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

TABLE 4. THE MINERAL CONTENTS (mg/100g) OF THE TRADITIONAL, BRINE AND BACKSLOPPING-FERMENTED "FUFU" FLOUR SAMPLES

Parameters	TFS	BFS	BSFS
Ca	0.162 ± 0.003^b	0.235 ± 0.004^a	0.171 ± 0.004^c
Mg	0.091 ± 0.003^a	0.040 ± 0.003^c	0.022 ± 0.003^b
P	0.152 ± 0.004^a	0.057 ± 0.002^b	0.071 ± 0.003^c
Na	0.097 ± 0.011^b	0.555 ± 0.055^a	0.158 ± 0.004^b
K	0.151 ± 0.003^b	0.504 ± 0.009^a	0.202 ± 0.007^c

Values are means and standard deviation of triplicate determinations.
Means with the same superscript in the same column are not significantly different ($P \leq 0.05$).
BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

The functional properties of the *fufu* flours are presented in Table 3. The swelling index and the WAC followed similar trends. The mean values obtained for BD in the traditional- and brine-fermented samples did not show any significant difference ($P < 0.05$). The three fermented samples were significantly different ($P < 0.05$) in their WAC with the highest ($4.89 \pm 0.06\%$) recorded in the traditional-fermented sample.

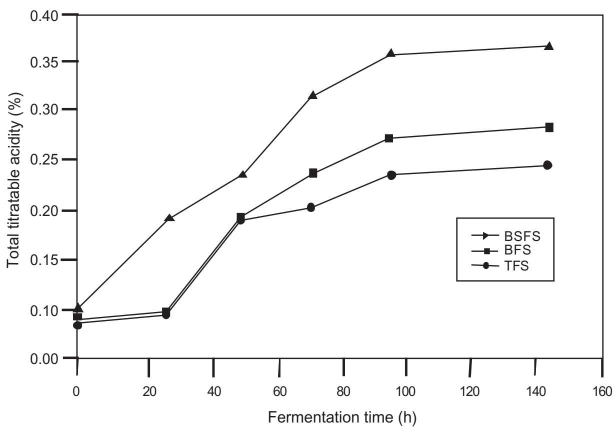

FIG. 4. CHANGES IN THE TOTAL TITRATABLE ACIDITY LEVELS DURING THE FERMENTATION OF CASSAVA ROOTS FOR "FUFU" PRODUCTION
BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

The mineral elements of the cassava "fufu" flour samples from the three fermentation techniques are shown in Table 4. The mean values of Mg and P of the brine and backslopping-fermented "fufu" flour samples were significantly ($P < 0.05$) lower as compared with the traditional-fermented sample. Noticeably were the significantly ($P < 0.05$) high mean values of Na and K obtained from the brine-fermented sample.

The result of the sensory evaluation for the taste, aroma and overall acceptability showed that the brine-fermented sample was the most acceptable to the panelist. While the backslopping-fermented sample was preferred in terms of color and texture. The traditional-fermented sample was the least accepted of the three samples. The result is presented in Table 5A–E.

All the LAB isolated during the fermentation process were strains of *Lactobacillus* except for the *Pediococcus* spp.

TABLE 5A. EFFECT OF FERMENTATION TECHNIQUES ON THE COLOUR OF COOKED "FUFU" DOUGH

Samples	A	B	C	D	E	F	G
BFS	0	0	0	4	5	1	0
TFS	0	1	2	5	1	1	0
BSFS	0	0	0	1	2	4	3

1, extremely bad; 2, very bad; 3, bad; 4, average; 5, good; 6, very good; 7, excellent; BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

TABLE 5B. EFFECT OF PROCESSING TECHNIQUES ON THE TASTE OF "FUFU" DOUGH

Samples	A	B	C	D	E	F	G
BFS	0	0	0	1	2	3	4
TFS	0	0	5	5	0	0	0
BSFS	0	0	0	3	4	1	2

1, extremely bad; 2, very bad; 3, bad; 4, average; 5, good; 6, very good; 7, excellent; BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

TABLE 5C. EFFECT OF PROCESSING TECHNIQUES ON THE ODOUR OF "FUFU" DOUGH

Samples	A	B	C	D	E	F	G
BFS	0	0	0	0	6	2	2
TFS	3	5	2	0	0	0	0
BSFS	0	0	0	4	6	0	0

1, extremely bad; 2, very bad; 3, bad; 4, average; 5, good; 6, very good; 7, excellent; BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

TABLE 5D. EFFECT OF PROCESSING TECHNIQUES ON THE TEXTURE OF "FUFU" DOUGH

Samples	A	B	C	D	E	F	G
BFS	0	0	1	1	6	2	0
TFS	0	0	0	5	4	1	0
BSFS	0	0	0	0	4	4	2

1, extremely bad; 2, very bad; 3, bad; 4, average; 5, good; 6, very good; 7, excellent; BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

this finding is similar to previous reports by Oyewole (1991); Kobawila *et al.* (2005) and Sobowale *et al.* (2007). The high level of LAB present in the different fermentations studied confirm the importance or relevance of this group in the fermentation as reported by Oyewole and Odunfa (1990) and Sobowale *et al.* (2007). The involvement of *L. plantarum*, *L. buchnerii*, *L. casei* and *Pediococcus* spp. in the brine fermentation of cassava to produce "fufu" has not been reported. But *L. plantarum* has been reported as the predominant LAB in brine fermentation of vegetable (Steinkraus 1996). These LAB that were implicated in brine fermentation of cassava roots may be due to their ability to withstand the concentration of the brine (4%) employed in the fermentation process.

The occurrence of *Saccharomyces cerevisiae* and *Candida species* as the prevalent yeasts during the fermentation process has been reported by Oyewole and Odunfa (1990). The two Coliforms bacteria isolated during the fermentation process, which were later eliminated as the fermentation progressed, could either be indegenous flora of the cassava or could have found their way into it during the preparation and handling of the samples for fermentation (Adegoke and Babalola 1998). The gradual reduction in the pH as the fermentation progressed is similar to the report of Mahingu *et al.* (1987). The mean values of the pH after 96 h of fermentation agreed with the findings of Kobawila *et al.* (2005). The increase in the TTA as the fermentation progressed is in accordance with the reports of Oyewole and Ogundele (2001) and this increase can be attributed to the activities of the LAB on the carbohydrate of the cassava roots (Oyewole and Odunfa 1992)

The reduction observed in the HCN content of the "fufu wet cake" after 96 h of fermentation and processing may be a result of the activities of microbial enzymes during the fermentation process (Okafor 1983; Ejiofor and Okafor 1985; UNIFEM 1989; Kobawila *et al.* 2005). Also, the reduction in HCN of brine-fermented samples despite the insufficient retting of the cassava roots after 96 h of fermentation is unusual, but this reduction could probably be the result of grating employed after fermentation of the cassava roots (Westby and Gallat 1999). Further reduction in the HCN contents after processing the "fufu wet cake" into flour could be attributed to the heat (oven drying) applied in the processing of the "wet cake" into flour (Okoro 2007).

Variations in the proximate composition could be the result of the fermentation and processing techniques employed (Etudaiye *et al.* 2009 and Oyewole 1991). From the mean values of the proximate composition, it is easy to single out the brine- and backslopping-fermented "fufu" flour samples as having the best nutritional value.

The results of the functional properties show that traditional and brine fermentation techniques improve the WAC of "fufu" flour samples than the backslopping fermentation. Higher WAC observed in the brine-fermented flour sample could be as a result of the 4% NaCl (common salt) used for the fermentation (England 1975 and Fagbemi and Ijah 2004). The WAC is an important functional property required in food formulations, especially those involving dough handling such as fufu flours (Udensi *et al.* 2008). Therefore brine and traditional-fermented samples with higher WAC will meet this requirement. The low BD of "fufu" flour has also been reported by Etudaiye *et al.* (2009). The mean values of the BD obtained in all the three

TABLE 5E. EFFECT OF PROCESSING TECHNIQUES ON THE OVERALL ACCEPTABILITY OF "FUFU" DOUGH

Samples	A	B	C	D	E	F	G
BFS	0	0	0	0	3	3	4
TFS	1	2	4	3	0	0	0
BSFS	0	0	0	3	5	2	0

1, extremely bad; 2, very bad; 3, bad; 4, average; 5, good; 6, very good; 7, excellent; BSF, brine-fermented sample; TFS, traditionally fermented sample; BSFS, backslopping-fermented sample.

fermented fufu flour samples were similar to that of Udensi *et al.* (2008).

The lowest SI recorded in the backslopping-fermented sample may be due to the reported increase in microbial activity during the backslopping fermentation of the cassava roots (Okoro 2007). It could also be presumably due to the higher carbohydrate content in the flour sample (Leach *et al.* 1959; Ikegwu *et al.* 2009). The lower SI obtained in brine and backslopping-fermented samples offered a lighter and easy to digest "fufu" which could be preferred to the heavy stuff obtained from the traditionally processed "fufu" flour (Okoro 2007).

The mean values of Ca, Mg and P obtained for the three flour samples were higher than the values reported by Sobowale *et al.* (2007) for "fufu" flours fermented with starter culture. Except in the brine-fermented sample, the mean values of K obtained were higher than that of the Na (Olaofe and Sanni 1988; Aletor and Fetuga 1989 and Oshodi *et al.* 1999). Noteworthy is the significantly ($P < 0.05$) highest mean values of Na and K obtained in the brine-fermented sample. This could probably be due to the 4% NaCl used for the fermentation of the cassava roots. This implies that "fufu" flour can be fortified with Na and K through brine fermentation. These two elements are very essential in the flour. Apart from improving the taste of the flour, it also enhances the salt balance of the body fluid (Raimbault 1998). Several clinical studies have shown K and Ca to be effective pressure-lowering agent (Osborne *et al.* 1996). Hence, consumption of this African-fermented cassava roots product may help in reducing the blood pressure of the consumer.

The general preference for the brine-fermented sample may be due to the fact that brining produced some changes in the taste, texture and flavor of the product, which made it more acceptable to the panelist (Tandon *et al.* 1986; Ranken 1988; Steinkraus 1996).

CONCLUSION

This research work documents the successful fermentation of cassava roots using traditional, brine and backslopping fermentation techniques. The study shows that some strains of LAB, *Bacillus* and yeast can tolerate 4% brine fermentation of cassava roots. Efficient reduction in the HCN content can be achieved in "fufu" flour through brine and backslopping fermentation techniques. Higher protein, fat and carbohydrate together with low moisture contents obtained in brine- and backslopping-fermented samples are indicators of stable shelf life, cheap and available source of calories to the consumers. WAC of fufu flours helps in determining the extent to which water should be added during dough preparation and to improve handling characteristics. The results of the BD will guide the processors determining the packaging requirement of the flours. The brine- and backslopping-fermented sample were richer in K and Ca. This work contributes in providing useful information to the processors on the use of brine and backslopping fermentation techniques in the production of good quality fufu. Therefore, production of fufu with high nutritional value has the potential to help Nigeria improve its food security, raise employment and then generate income.

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