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Effects of blanching and controlled fermentation on nutritional properties of unripe plantain flour

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Abstract

This work investigated the combined effect of blanching and controlled fermentation on nutritional composition of unripe plantain (*Musa paradisiaca*) flour. Blanching and spontaneous fermentation of unripe plantain was carried out using standard procedures. Isolation and identification of Lactic acid bacteria (LAB) were carried out using culture-dependent method and morphological and biochemical characterization respectively. Fermentation of the unripe plantain using selected starters and nutritional properties were carried out using standard methods. The results obtained in this study revealed that pH of fermenting samples decreased from 6.9 – 4.7 and the total titratable acidity increased from 0.043 – 0.086. Isolates on MRS agar had the highest total viable count. *Lactobacillus plantarum, L. fermentum, L. bulgaricus* and *Leuconostoc mesenteroides* were isolated and identified. *L. plantarum* produced the highest antimicrobial compounds, had the highest ability to hydrolyse starch and its safety properties has been confirmed. Based on these parameters it was selected as starter cultures for the controlled fermentation of unripe plantain. *L. plantarum* fermented samples had the highest nutritional properties compared to the raw, blanched and spontaneous fermented samples. It can be concluded that the combined effect of blanching and controlled fermentation improved the nutritional property of unripe plantain flour.

Key words: Unripe plantain, Blanching, Spontaneous fermentation, Controlled fermentation, Nutritional properties

Introduction

Plantain is one of the most important crops of the tropics which originated from India. It is identified as plantain in English,'*Ogede agbagba*' in Yoruba, '*Ayaba*' in Hausa and '*Ogadejioke*' in Igbo. Plantain requires about eight to twelve months for matured fruit to be harvested [1]. The fruit is widely consumed globally in Africa, North America, Asia, South America and according to FAO [2.], plantain is grown in 52 countries with world production of 33 million metric tonnes. In Nigeria, its wide consumption by various ethnic groups and socio–economic classes is due to availability of affordable cheap technology in conversion of the fruit to other value added products such as "*Boli"* (roasted plantain) which can be eaten with groundnut, stew or fried egg. In addition, the unripe plantain can be processed into plantain flour and constituted to Amala which can be eaten with soup. Furthermore, its slices can be fried into chips which are consumed by both rich and the poor people. It is an important staple crop which supplies up to 25% of the required carbohydrates for approximately 70 million people in the humid zone of sub–Saharan Africa [3].

Plantain contains high quantities of vitamins A, C and B groups and minerals such as calcium and iron. [5]. It is of high medicinal value and can be used in the treatment of bronchitis, dysentery and ulcer while the cooked flour is recommended for diabetic patients [4]. The astringent plant sap have been reported to be applied in cases of listeriosis epilepsy, leprosy, fevers, haemorrhages, acute dysentery and diarrhea, insect stings and bites [3].

A major problem associated with plantain is the highly perishable nature of its fruit with an average market life of 1 to 10 days, compared with several weeks for yam [6]. The short shelf life could be attributed to the presence of high moisture content which support the growth and proliferation of spoilage bacteria [7]. Both combination of fermentation and conversion of unripe plantain to other valuable product can lead to its availability year in year out [8]. Several methods can be employed in shelf life extension of plantain such as processing the mature unripe plantain to chips, bread, cakes, biscuits, flour [9]. Fermentation is one of the methods employed by many people or organization in the production of flours [10] because it is a low–cost technology preventing food spoilage and food–borne diseases and can be employed to diversify series of under exploited plant foods like plantain. However this process results in the bioconversion of raw materials into new products with gross improvement in nutritional status, shelf life and organoleptic properties [10, 11]

The high consumption pattern of unripe plantain flour among different ethnic groups in Nigeria is well documented [12, 13, and 14]. Methods such as peeling, cutting drying and milling are employed in the production process of unripe plantain into flour. However there is dearth of information on the use of blanching and controlled fermentation in the production process of unripe plantain flour. This research work is intended to provide baseline information on the combined effects of blanching, spontaneous and controlled fermentations on the nutritional status of unripe plantain flour

Materials and methods

Sample Collection:

Unripe plantain samples (*Musa paradisiaca)* were obtained from Oje, Ayeye and Oritamerin Markets in Ibadan, Oyo state, Nigeria and transported to the Postgraduate Research Laboratory of Microbiology Department, University of Ibadan for further work.

Treatment of Samples

One thousand five hundred grams (1.5kg) of unripe plantain samples were washed, peeled and cut into uniform–sized pieces of 1cm thick which was confirmed using a transparent meter rule [15] and soaked in boiled water for 10 min (blanching).Five hundred grammes of this blanched sample was dried and milled using hammer mill and its nutritional properties were determined using the method described by A.O.A.C [16].

Another 500 g of the blanched slices was cooled and allowed to ferment naturally for 48hrs and microbial analysis, pH and total titratable acidity (TTA) were determined at 6h intervals. The plantains slices were harvested, dried and hammer milled and the nutritional properties determined.

The remaining 500g of the blanched unripe plantain sample was transferred into 2L sterile Erlenmeyer flask containing 1000ml sterile distilled water. This was steamed in water bath set at 85°C for 10 min and cooled to 30°C and inoculated with 10ml saline suspension of the *Lactobacillus plantarum* (containing 1.84×10^6 cfu/ml) obtained from spontaneous fermentation mentioned above. The flask was incubated at 30 °C for 48 h and pH and total titratable acidity were determined at 6h intervals. The starter fermented unripe plantains were harvested, dried, hammer milled and nutritional properties were determined.

Determination of pH

The changes in pH of fermenting samples were monitored at 6h intervals for 48 h using a ROHS pH meter (HANNAH Instruments, Italy) [3]

Determination of Total Titrable Acidity (TTA)

The Total Titrable Acidity (TTA) was determined according to the method described by [3] using the equation below:

% Lactic acid = A× 0.009× 100/v
Where A= ml of 0.1m NaOH and V= ml of sample taken for test (=25ml)

Isolation of Microorganisms from spontaneously fermenting unripe plantain

The fermenting unripe plantains were agitated for 2 min before sampling to ensure uniform mixing. The sample was serially diluted and 0.1ml of appropriate dilutions were plated on De Man, Rogosa and Sharpe (MRS), MacConkey and yeast extract agar (YEA) using pour plate method. MRS plates were incubated anaerobically at 37 °C for 48h. MacConkey agar plates were incubated aerobically at 37°C for 24h while YEA plates were incubated at 28°C for 5days. The plates were examined for microbial growth and microbial colonies on each plate were counted. The colonies observed were sub cultured several times until pure colonies were obtained which were transferred on to agar slants in MacCartney bottles and stored in refrigerator at 4°C [15]

Identification of bacterial Isolates from spontaneously fermenting unripe plantain

The pure isolates were identified based on morphological and biochemical characterization as described [15].

Selection of starter culture
Selection of starter cultures from among the bacteria isolated from spontaneously fermenting unripe plantain was based on the following parameters:

(i) Occurrence of bacteria throughout the fermentation period
(ii) production of antimicrobial compounds by bacteria
(iii) starch hydrolysis ability of bacteria
(iv) safety properties of bacteria

(i) Occurrence of bacteria throughout the fermentation period

This was monitored by plating 0.1ml of the fermenting water on MRS agar, MacConkey and YEA plates at 6h intervals and incubated at their respective incubation periods and temperature for growth. Each plate was examined for microbial

growth and the number of microbial colonies seen on each plate was counted and recorded

(ii) Production of antimicrobial compounds

Determination of lactic acid produced by the lactic acid bacteria was calculated using the formula titratable acidity of lactic acid

$$= mLNaOH \times NNaOH \times M.E \times 100$$

Where

mLNaOH = volume of NaOH used,
N NaOH = Normality of NaOH,
M.E = Equivalent factor = 90.08 [18]

Determination of Diacetyl produced by Lactic acid bacteria

This was determined using the formula

$$\frac{Ak = (b - s)\ (100 - e)}{W}$$

Where Ak = percentage of diacetyl,
b = Number of mL of 0.1 N HCI consumed in titration of the sample,
e = Equivalence factor = 21.52 mg,
W = Volume of sample and
S = Number of mL of 0.1 N HCI consumed in titration of residual sample [16]

Determination of Hydrogen peroxide produced by lactic acid bacteria

This was determined using the formula

H_2O_2 Concentration =

$$\frac{\text{mL KMnO4} \times \text{N KMnO4} \times \text{M.E} \times 100}{\text{mL H2SO4} \times \text{Volume of Sample used}}$$

Where mL $KMnO_4$ = volume of $KMnO_4$ used, N $KMnO_4$ = Normality of $KMnO_4$, M.E = Equivalent factor = 90.08, mL H_2SO_4= volume of H_2SO_4 used [16]

Starch Hydrolysis by Lactic acid bacteria

This was carried out as described by Fadahunsi *et al* [17]. Occurrence of clear zones along the lines of streak indicated a positive result.

Safety assessment of the lactic acid bacteria

Safety tests such as haemolysis, gelatinase and DNase were carried out according to the method of Nabil *et al* [18].

Production of DNase : DNase agar was prepared and Methyl green indicator was added and sterilized at 121°C. The agar was poured into plates and LAB isolates were inoculated on the DNAse agar and incubated at 37°C for 48 h. LAB isolates without halos-formation or clear zone formation around the colonies were selected for further studies.

Production of β-haemolysin by LAB was determined on Blood Agar (Oxoid) containing 5% defibrinised horse blood after 48 h of incubation at 37°C. Zones of clearing around colonies indicated β-haemolysin production. Isolates without clearance around were selected for further studies.

Gelatinase production test was carried out by preparing Nutrient gelatin according to the manufacturer's instruction in test tubes and sterilized at 121°C for 15mins. It was cooled and each LAB isolates was inoculated into the sterile nutrient gelatin and incubated at 25°C for 7 days along with control tube free from the test organism. After 7 days, the tubes were placed in the refrigerator and later brought out for gelatin liquefaction in which positive tubes were liquid while negative tubes remained solid as control tube.

Flour preparation

The blanched, blanched spontaneously fermented, blanched controlled fermented and raw samples of unripe plantain were dried for 24 h at 60 °C in an oven. The dried chips were milled in a hammer mill to pass through a 0.8mm sieve. The flour was packed in cellophane bags until used to determine its nutritional properties.

Proximate Analysis of samples of unripe plantain flour

Moisture, fat, protein, fiber and carbohydrate contents of unripe plantain flour were determined according to the methods described by AOAC [16]

Mineral analysis of samples of unripe plantain flour

These were determined according to the methods described by AOAC [16]

Statistical analysis

The data generated in this research work were subjected to Analysis of Variance (ANOVA) using SPSS 19.0 version software The significance of difference was tested at the level $_{p=0.05.}$

Results

The results of pH and Total titratable acidity during spontaneous and controlled fermentation of unripe plantain is shown in Table 1 It was observed that the pH during spontaneous fermentation decreased from 6.9 at oh to 4.7 at the end of the fermentation while the pH during controlled fermentation also decreased from 6.7 at 0h to 4.5 at the end of the fermentation period

The total titratable acidity during spontaneous fermentation of unripe plantain was observed to increase from 0.043 at 0h to 0.086 at the end of the fermentation period while total titratable acidity during controlled fermentation of unripe plantain was observed to increase from 0.054 at 0h to 0.090 at the end of the fermentation period.

Table 1. pH and Total titratable acidity during spontaneous and controlled fermentation of unripe plantain

Time(h)	Spontaneous fermentation		Controlled fermentation	
	pH	Total titratable acidity	pH	Total titratable acidity
0	6.9	0.043	6.7	0.054
6	6.6	0.050	6.4	0.058
12	6.4	0.058	6.2	0.065
18	6.2	0.065	6.0	0.068
24	6.0	0.072	5.8	0.076
30	5.8	0.076	5.5	0.079
36	5.6	0.079	5.0	0.083
42	4.8	0.083	4.6	0.086
48	4.7	0.086	4.5	0.090

The result of total viable count of microorganisms during spontaneous fermentation of unripe plantain was shown in Table 2. The result showed that the Enterobacteriaceae colony count on MacConkey agar decreased from 1.1 x 10^3 cfu/ml at 6h to 1.1 × 10^1 cfu/ml at 18h after which no growth was observed. No growth was seen on yeast extract agar till 18h, but at 24h a growth of 6.1x10^2 cfu/ml was observed which increased to 3.4 x 10^4 cfu/ml at the end of the fermentation period. However LAB count on MRS agar increased from 2.91 x 10^3 cfu/ml at 6h to 2.48 x 10^9 cfu/ml at the end of the fermentation period. Lactic acid bacterial isolates on MRS agar had the highest viable count during spontaneous fermentation and featured the fermentation period hence was selected as potential starter culture.

Results of the morphological, physiological and biochemical characterization tests showed that LAB isolates obtained from the spontaneous fermentation of unripe plantain belonged to four species namely *Lactobacillus plantarum, L. fermentum, L. bulgaricus* and *Leuconostoc mesenteroides.* The most frequently occurring of the LAB isolates is *L. plantarum* with frequency of occurrence of 39.3% followed by *L. fermentum* (27.4%), *L. bulgaricus* (17.7%) and *Leuconostoc Mesenteroides* (15.7%).

Table 2. Total viable count of microorganisms (cfu/ml) isolated during Spontaneous fermentation of unripe plantain

Time (h)	Enterobacteriaceae	Yeast	LAB
0	–	–	–
6	1.1 × 10^3	–	2.91 ×10^3
12	1.1 × 10^2	–	9.00 ×10^5
18	1,1 × 10^1	–	2.03×10^6
24	–	6.1 × 10^2	2.18 ×10^6
30	–	1.7 × 10^3	2.27×10^7
36	–	4.5 × 10^3	2.13×10^7
42	–	2.9 × 10^3	2.07×10^8
48	–	3.4 × 10^4	2.48 ×10^9

Table 3 depicts the production of inhibitory compounds, starch hydrolysis, and safety assessment of the LAB species isolated from the spontaneous fermentation of unripe plantain slices. It was observed that *L. plantarum* produced the highest quantities of antimicrobial compounds tested as follows: 1.77 mg/l of lactic acid, 0.89 mg/l of diacetyl, and 0.0085 mg/l of hydrogen peroxide. Equally, it had the highest zone of starch hydrolysis (12.0 mm) and tested negative in all the safety assessments carried out. Based on this result, *L. plantarum* was selected and used as a starter for the controlled fermentation of unripe plantain samples.

The results of proximate analysis of raw, blanched, blanched spontaneously fermented and blanched controlled fermented unripe plantain samples were shown in Table 4.

Table 3. Production of inhibitory substance, zone of starch hydrolysis and safety assessment of the LAB species isolated from spontaneously fermented plantain slices

ISOLATES/CODE	LA(mgl^{-1})	DA(mgl^{-1})	H_2O_2(mgl^{-1})	SHT(mm)	Dnase	Beta-Hemolysis	Gelatinase
L. fermentum/LFA	0.89	0.54	0.0068	7.5	–	–	–
L. plantarum /LPA	1.51	0.62	0.0079	12.0	–	–	–
L. bulgaricus /LBA	0.68	0.47	0.0051	2.5	–	–	–
Leu mesenteroides/LMA	0.44	0.32	0.0034	1.0	–	–	–
L. fermentum/LFB	0.71	0.57	0.0071	8.0	–	–	–
L. plantarum /LPB	1.77	0.89	0.0085	10.0	–	–	–
L. bulgaricus/ LBB	0.46	0.36	0.0040	3.5	–	–	–
Leu mesenteroides/LMB	0.43	0.32	0.0033	0.5	–	–	–

The highest moisture content was recorded in blanched samples (15.29 ±0.01), followed by blanched spontaneously fermented samples (13.36±0.01), raw samples (11.22±0.01) and the blanched controlled fermented samples (11.09±0.01) with the least moisture content. The highest protein content was recorded in raw samples (8.16 ±0.01), followed by blanched samples (7.32±0.01), blanched controlled fermented samples (7.15±0.01) and the

least was recorded in blanched spontaneously fermented samples (6.17±0.01). The highest crude fiber was recorded by blanched controlled fermented samples (6.89 ±0.01), followed by raw samples (6.87±0.01), followed by blanched samples (3.13±0.01) and the least was recorded by blanched spontaneous fermented samples (2.94±0.01). The highest fat content was recorded by raw samples (1.27±0.01), followed by blanched samples (0.94±0.01), followed by blanched controlled fermented samples (0.79±0.01) and the least was recorded by blanched spontaneous fermented samples (0.40±0.01). The highest ash content was recorded by raw samples (3.16 ±0.01), followed by blanched samples (2.83±0.01), followed by blanched spontaneous fermented samples (0.98±0.01) and the least was recorded by blanched controlled fermented samples (0.26±0.01). The highest carbohydrate content was recorded by blanched controlled fermented samples (74.72 ±0.01), followed by blanched spontaneous fermented samples (73.20±0.01), followed by blanched samples (71.40±0.01) and the least was recorded by raw samples (70.45 ^{a} ±0.01).

The result of mineral analysis of raw, blanched blanched spontaneous and blanched controlled fermented plantain samples and blanched were shown in Table 5. The raw plantain had the highest mineral content with 0.019% Iron, 0.134% Potassium, 0.045% Sodium and 0.049% Calcium while the least Iron and Potassium content were found in blanched spontaneously fermented plantain samples with 0.004% and 0.008% respectively. However, the least sodium content of 0.015% was found in blanched controlled fermented unripe plantain samples and least calcium content (0.031%) was found in sample blanched spontaneous and blanched controlled fermented samples.

Table 4. Proximate analysis of raw, blanched spontaneous fermented, blanched controlled fermented and blanched samples of unripe plantain flour

Samples	Moisture (%)	Crude protein (%)	Crude fiber (%)	Fat (%)	Ash (%)	Carbohydrate (%)
Raw	11.22 ^{a} ±0.01	8.16 ^{a} ±0.01	6.87 ^{a} ±0.01	1.27 ^{a} ±0.01	2.03 ^{a} ±0.01	70.45 ^{a} ±0.01
blanched Spontaneous fermented	14.91 ^{b} ±0.01	7.07 ^{b} ±0.01	2.94 ^{b} ±0.01	0.40 ^{b} ±0.01	1.48 ^{b} ±0.01	73.20 ^{b} ±0.01
blanched Controlled fermented	10.19 ^{c} ±0.01	7.15 ^{c} ±0.01	6.89 ^{c} ±0.15	0.79 ^{c} ±0.01	0.26 ^{c} ±0.01	74.72 ^{c} ±0.01
Blanched	14.38 ^{d} ±0.01	7.32 ^{d} ±0.01	3.13 ^{d} ±0.01	0.94 ^{d} ±0.01	2.83 ^{d} ±0.01	71.40 ^{d} ±0.01

Table 5: Mineral analysis of raw, blanched, starter fermented and spontaneously fermented samples of unripe plantain flour

Plantain Samples	Iron (mgl^{-1})	Potassium (mgl^{-1}	Sodium (mgl^{-1})	Calcium (mgl^{-1})
Raw	0.0220^{a} ±0.001	0.0322^{a} ±0.000	0.0240 ^{a} ±0.001	0.0218 ^{a} ±0.001
Spontaneously fermented	0.0210^{b} ±0.001	0.0319^{b} ±0.001	0.0231^{b} ±0.001	0.0216 ^{b} ±0.001
Controlled fermented	0.0211 ^{c} ±0.001	0.0320^{c} ±0.001	0.0229 ^{c} ±0.001	0.0216^{c} ±0.001
Blanched	0.0219^{d} ±0.001	0.0321^{d} ±0.000	0.0233 ^{d} ±0.001	0.0217 ^{d} ±0.001

The values are means of three replicate±standard deviation. Mean values with similar superscript across the column are not significantly different

Discussion

This study provided information on combined effect of blanching and fermentation on nutritional properties of unripe plantain flour. The decrease in pH observed in spontaneous and controlled fermentation in this study could be attributed to hydrolysis of complex organic compound by fermenting microorganisms which resulted in production of acid and ethanol [4]. However, this finding showed that an acidic fermentation occurred naturally with the growth of lactic acid bacteria in the fermentation environment. This observation is in conformity with the findings of Achi and Akubor [15], Fadahunsi *et al.*[17] and Wakil *et al.*[19]. In addition, Omemu *et al.* [20] had earlier reported that high total titratable acidity in fermented food had been suggested to reduce the incidence of diarrhea in consumers.

The isolation and identification of LAB from spontaneous fermentation of food had earlier been reported by Ogunbanwo *et al.* [21] and Adesokan *et al.* [22]. Their existence in fermenting environment

may be due to their ability to adapt, survive and utilize nutrient in the environment for growth and metabolism. In addition, Nabil et al. [18], Wakil *et al*.[19] and Omemu *et al*. [20] had earlier reported the isolation of LAB from fermented foods.

The observed domination of *Lactobacillus plantarum* during fermentation of unripe plantain could be due to ability of the organism to produce inhibitory metabolites thereby inhibiting some other fermenting organisms. These substances confer inhibitory potential on LAB and give them competitive advantage in their existing niche. The mechanism of inhibition of LAB is by dissociating the acid into ionic form which penetrates the cytoplasmic membrane of target organisms to cause intracellular acidification as well as break down of trans– membrane proton motive force. According to Ishola and Adebayo-Tayo [23], LAB are the highest lactic acid producing bacteria worldwide This optimum production of lactic acid is in conformity with the findings of Achi and Akubor [15], Ishola and Adebayo-Tayo [23] Fadhunsi *et al*.,[17] and Wakil *et al*.[19]. The domination of LAB is an indication of its starter culture potential. The selection parameters used in this study showed that LAB had the highest performance which led to its selection as a starter culture and the result of safety assessment of LAB showed that they are all GRAS and are suitable to be used as starter culture in food fermentation [19].

The lowest moisture content observed in the starter fermented unripe plantain sample is an indication of microbial safety and increasing shelf life [24,25 and 26] This observation is in conformity with the work of Wordu and Akusu [27]. There was general significant decrease in protein content of all the samples. This finding is in conformity with the findings of Wordu and Akusu [27]. According to Okareh *et al.* [1] protein is crucial in human diet because it is needed for physiological and survival of animals and human beings. According to Nkhata *et al.*[29] the effect of fermentation on protein content of food has yielded inconsistent results likely due to different experimental designs, study durations and variation in the initial protein or amino acid profile of foods. Chaven and Kadam [30], Doudu *et al.*[31], El-hag *et al.* [32] and Pranato *et al*. [33] reported increase in protein content, while Falola *et al.* [27], Pranato *et al*. [33] and Olatubi and Ojokoh [34] observed decrease in protein content during fermentation of food. The decrease in protein content observed in this study might have resulted from enzymatic hydrolysis of protein into simple compounds such as amino acid which are utilized by fermenting organisms. The use of amino acid by fermenting microorganisms lead to lower protein content [27 and 33]

The increase in fibre content recorded in starter fermented plantain sample had earlier been reported by Olatubi and Ojokoh [34]. Fibre is an indigestible component of food material that helps in improving roughage and bulk as well as contributes to a healthy condition of the intestine [36 and 37]. In addition, the importance of fiber is seen in regulating physiological functions in the body. The lowest significant decrease observed in the fat content of the starter fermented plantain sample had earlier been reported by Fadhunsi *et al.* [17] and this observation could be due to degradation of fat to lipid [4]. This reduction of fat will lead to lowering of the cholesterol level in the blood and thus make the starter fermented samples a good prescriptive diet for obese and hypertensive patients.

The lowest significant decrease observed in the ash content of the starter fermented sample had earlier been reported by Omafuvbe *et al.*[38] and Michodiehoun-Mestres [39]. According to Eremosele *et al.*[3], ash is an inorganic residue which determine the total amount of mineral in food component. The decrease in ash content could be linked with leaching of water soluble minerals during fermentation. However, the decrease in an ash content indicated complete utilization of minerals for metabolism by fermenting microorganisms [40 , 33 and 3]. In addition, Low ash content had been reported to aid better growth performance and feed utilization efficiency with simultaneous increase in the amount of metabolisable energy [13].

The highest significant increase observed in the carbohydrate content of the starter fermented sample had earlier been reported by Adepoju *et al.*[41]. This occurrence could be due to decrease in protein content of the starter fermented samples [38]. However, Nabil *et al*. [18] reported that highest carbohydrate content would lead to more energy supply when consumed. The significant highest carbohydrate content of starter fermented sample observed is an indication that it would supply more energy when consumed. However Adepoju *et al.* [41] reported that processing has been reported to improve carbohydrate availability in a more digestible form.

The observed significant decrease in mineral contents of the three samples had earlier been reported by Adepoju *et al.* [41]. This observation might be due to effect of fermentation and blanching which led to significant loss in all the minerals. However, Egbuonu *et al.* [43] reported that the extent of soaking in water would reduce the mineral content of processed food. While Liang *et al.* [44], Mohite [45] and Nkhata [29] explained that some fermenting microorganisms degrade fiber and

transform tannins to phenols during fermentation. These activities led to inhibition of mineral bioavailability. In addition, the low sodium content of the three samples makes them suitable as a diet for hypertensive patients.

Conclusion

It can therefore be concluded that blanched starter fermented samples with *Lactobacillus plantarum* have the best nutritional qualities.

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