Nutritional Properties and Antinutritional Factors of Corn Paste (Kutukutu) Fermented by Different Strains of Lactic Acid Bacteria

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The aim of this study is to reduce antinutritional factors and to improve the nutritional properties of Kutukutu during fermentation with Lactic Acid Bacteria (LAB). For that, Kutukutu (700 g) was prepared in the laboratory and inoculated with pure cultures of LAB (10⁹ CFU/mL). Then, preparation was incubated for 120 h. Every 24 h, Kutukutu were collected, dried at 45°C for 24 h, and analyzed. The results showed that Lactobacillus brevis G25 increased reducing sugars content to 80.7% in Kutukutu after 96 h of fermentation. Lactobacillus fermentum N33 reduced the starch content to 73.2%, while Lactobacillus brevis G11, L. brevis G25, and Lactobacillus cellobiosus M41 rather increased the protein content to 18.9%. The bioavailability of Mg and Fe increased, respectively, to 50.5% and 70.6% in the Kutukutu fermented with L. brevis G25. L. plantarum A6 reduced the tannin content to 98.8% and L. buchneri M11 reduced the phytate content to 95.5%. The principal component analysis (PCA) shows that, for a best reduction of antinutrients factors and improvement of protein content and minerals, Kutukutu must be fermented by L. brevis G25 and L. fermentum N33, respectively. These starter cultures could be used to ameliorate nutritional proprieties of Kutukutu during the fermentation.

1. Introduction

The production of fermented corn paste by natural fermentation of grains soaked in water and ground is an artisanal transformation process of maize commonly used in Africa [1]. Such fermented corn paste can take many denominations in different countries. In Nigeria, for example, the fermented paste is called “Ogi” while in South Africa the term commonly used is “Mawë” [2]. In Cameroon, particularly in North Region, they call it “Kutukutu” [3]. This Kutukutu has an important place in the sociocultural and nutritional plan. In the sociocultural plan, Kutukutu is taken regularly during fast periods and is frequently used as complementary foods for infants [4]. In Cameroon, 70% of mothers give porridge prepared with Kutukutu to infants during the weaning period [5]. Moreover, it is a major source of proteins, carbohydrates, and calories in the diets of large number of population [6]. However Kutukutu contains many antinutritional factors such as phytic acid, polyphenols, and tannins which reduce bioavailability and digestibility of proteins and carbohydrates through formation of complex with minerals and inhibition of enzymes [7]. The technological processes such as mechanical, thermal, chemical, and biological processes are used to reduce antinutritional factors content and to improve the bioavailability of nutrients. Unlike thermal, chemical, and mechanical processes which can deteriorate quality of food, fermentation is one of the processes that decreases the level of antinutrients in food grains and increases the starch digestibility, protein digestibility, and nutritive value [4]. Among the microorganisms used in food fermentation, the LAB represents the principal group found on various substrates [8]. LAB are a large group of closely related bacteria that have similar properties such as lactic acid production, which is an end product of the fermentation. This LAB group includes Lactobacillus, Lactococcus, Streptococcus, and Leuconostoc species. Lactic fermentation is a common way
of preparing traditional fermented food in Africa like maize porridge, alcoholic beverages, and dairy products. Several studies reported that LAB improve the nutritional quality of foods during fermentation by increasing the protein content, reducing sugar content, reducing the antinutritional factors (phytates, tannins, and polyphenols), improving the bioavailability of minerals [9], and increasing the energy density by hydrolyzing starch into simpler compounds such as glucose and fructose [10]. Although natural fermentation improves nutritional value and organoleptic qualities of foods [9], it has a major problem of fluctuation in the quality of different foods obtained [11]. Indeed, the spontaneous fermentation process that is carried out by the development of epiphytic microflora can lead to undesirable products on the organoleptic, microbiological, or toxicological quality [11]. That is why the natural fermentation is often the main cause of diarrhea and malnutrition in children [12].

To solve this problem, there is a crucial need to isolate and identify LAB with specific physiological and metabolic properties, which can be used as starters in view to improve general food quality and nutritional value as suggested by few authors [13–17]. The aim of this study is to reduce antinutritional factors and to improve the nutritional properties of Kutukutu during fermentation with L. brevis G11, L. brevis G25, L. buchneri M11, L. cellobiosus M41, L. fermentum N11, L. fermentum N25, and L. plantarum A6. These lactic starters stored at 4°C for 72 h. The perfect lyophilized colonies were inoculated in test tubes containing 10 mL of MRS broth and incubated at 30°C for 16 h. The resulting preparation was centrifuged at 3000 rpm for 10 min and the resulting pellet was washed in 10 mL of physiological peptone water (peptone 1g in saline solution (0.85% NaCl), pH 7.2) and centrifuged again. The pellet obtained was suspended in 10 mL saline water. The concentration of viable cells was adjusted at 10^9 CFU/mL using McFarland Standard tube number 4.

2.2. Production of Kutukutu. In order to evaluate the influence of LAB on the nutritional properties of the Kutukutu during fermentation with starters, the Kutukutu was produced under laboratory conditions following the traditional process with some modifications. Dry corn purchased from a local market in Ngaoundere (Adamaoua, Cameroon) was decontaminated in sterile distilled water containing benzoic acid 6% (w/v) (E210) for 24 h at room temperature. Then sterile corn was soaked in sterile distilled water for 48 h at room temperature. Grinding was proceeded after the determination of the water content (39.6%) using a metallic grinding mill. The paste obtained was mixed (1/3 w/v) with sterile distilled water and sieved through a sieve of mesh 200 μm. After decantation for 24 h at room temperature, the paste was collected (water content 73%) in a sterile container and kept for inoculation and fermentation.

2.3. Fermentation of Kutukutu. Flasks containing 700 g of previously described paste were inoculated separately with 1 mL containing 10^9 CFU of L. brevis G11, L. brevis G25, L. buchneri M11, L. cellobiosus M41, L. fermentum N11, L. fermentum N25, and L. plantarum A6. These flasks were covered and kept at 25°C for 120 h. The preparations were then homogenized on daily basis to enhance the distribution of bacteria in the medium. Aliquots were collected every 24 h, dried at 45°C for 24 h, and analyzed. The control sample was the same paste without LAB. Diagram of inoculation of Kutukutu with LAB in laboratory is reported in Figure 1.

2.4. Changes of Physicochemical Parameters in Kutukutu. To assess the physicochemical parameters, the pH was measured according to the method described by Afoakwa et al. [18]. The lactic acid content was determined by titration according to Obadina et al. [19] and was expressed in grams of lactic acid per 100 g of sample. Reducing sugar was determined by the method described by Fischer and Stein [20] and the optical densities were read at 540 nm. The standard curve was drawn using a prepared aqueous solution of maltose.

The starch was determined by Jarvis and Walker method [21]. The optical densities were read at 580 nm. Standard curve was obtained using an aqueous solution of starch. The total nitrogen content (N × 6.25) was determined after digestion of the samples according to the Kjeldahl method described by AFNOR [22] and the coloration was determined by the method of Devani et al. [23]. Standard curve was obtained using a solution of ammonium sulfate.

Minerals like iron (Fe), potassium (K), manganese (Mn), magnesium (Mg), zinc (Zn), copper (Cu), calcium (Ca), and sodium (Na) were determined by atomic absorption spectroscopy (Benton et al.) [24]. The phosphorus was determined using ammonium molybdate complex method described by Murphy and Riley [25].

The phytates content was determined by the colorimetric method described by Vaintraub and Lapteva [26], modified by Gao et al. [27], and the optical densities were read at 500 nm using a spectrophotometer. Standard curve was obtained using a solution of phytic acid.

The total polyphenols content and tannins were determined by the method of Marigo [28]. The optical densities were read at 725 nm. The formula below was used to determine the tannin content:

\[
\text{Tannin (mg/100 DM)} = \frac{\text{Total Polyphenols (mg/100 DM)}}{\text{Nontannin polyphenols (mg/100 DM)}} \tag{1}
\]
2.5. Statistical Analysis. The results were analyzed using Statgraphics 5.0 (1998) software for the analysis of variance (ANOVA), calculation of averages, and standard deviations. Differences between means were tested using the Duncan Multiple Range Test. Sigma plot 11.0 software was used to draw the curves.

3. Results and Discussion

3.1. Changes in pH. Generally, the pH of Kutukutu fermented with the different LAB trains decreased with time compared to the control (Figure 2). However, Kutukutu fermented with L. brevis G25 had the lowest pH (2.7) after 120 h. The decrease of pH is due to hydrolysis of carbohydrates during the fermentation which was followed by the production of organic acids [11]. Studies made by Ali and Mustafa [29] showed a similar reduction of pH from 4.3 to 3.4 in the sorghum dough fermented with the lactobacilli strains (L. fermentum, L. brevis, and Lactobacillus amylovorus) after 6 h at 37°C.

3.2. Changes in Lactic Acid. Contrarily to pH, acidity of Kutukutu increased significantly with time ($P < 0.05$) compared to the control (Figure 3). It was noted that L. brevis G25 had the highest acidity range (from 0.3 to 1.2%) during fermentation of Kutukutu. The increase of the acidity reflects the metabolism of sugars by LAB during fermentation [30]. From the organoleptic point of view, the acidity of Kutukutu makes it more appetizing for anorexic children and may also reduce bacterial contamination [31, 32]. This result is in agreement with the study of Wedad et al. [33] who showed increase in acidity of sorghum cultivar “Mugud” and cultivar “Karamaka” from 0.36 to 1.6% and from 0.36 to 1.8%, respectively, after 16 h of spontaneous fermentation at 28°C. The work of Hounhouigan et al. [34] also showed similar increase in acidity (88%) of corn flour after 72 h of fermentation.

3.3. Reducing Sugar. The quantity of reducing sugars increased from 0 to 48 h of fermentation and then decreased after 48 h (Table 1). An increase of 130% in reducing sugars (from 168.2 to 387.6 mg/100 g DM) of Kutukutu fermented...
Table 1: Evolution of reducing sugars in the Kutukutu during fermentation by the various LAB at 25°C.

| Time (h) | Control | G11  | G25  | A6   | M11  | M41  | N25  | N33  |
|---------|---------|------|------|------|------|------|------|------|
| 0       | 168.2 ± 0.0d | 168.2 ± 0.0d | 168.2 ± 0.0d | 168.2 ± 0.0d | 168.2 ± 0.0d | 168.2 ± 0.0d | 168.2 ± 0.0d | 168.2 ± 0.0d |
| 24      | 168.0 ± 0.0d | 154.3 ± 3.5a | 189.5 ± 2.5c | 261.7 ± 10.5cd | 381.7 ± 6.2b | 2776 ± 15.5b | 3070 ± 2.5b | 2860 ± 18.7b |
| 48      | 160.3 ± 1.0c | 282.9 ± 2.2e | 291.4 ± 11.8d | 263.6 ± 10.3d | 387.6 ± 7.0c | 314.2 ± 13.8c | 321.8 ± 7.6c | 354.0 ± 17.3c |
| 72      | 160.2 ± 1.3c | 270.5 ± 4.8d | 296.1 ± 10.9c | 254.3 ± 7.9ed | 377.5 ± 5.2d | 309.3 ± 12.9d | 313.7 ± 5.2d | 2671 ± 17.3d |
| 96      | 157.1 ± 2.1bc | 250.6 ± 0.6c | 305.0 ± 9.9ed | 234.5 ± 11.9b | 321.3 ± 7.4c | 2870 ± 4.6c | 280.9 ± 6.8c | 218.2 ± 8.0c |
| 120     | 149.3 ± 2.4a | 246.4 ± 5.7c | 131.6 ± 6.9a | 2477 ± 4.1bc | 250.8 ± 0.0f | 210.0 ± 8.8f | 236.2 ± 9.3f | 215.8 ± 2.5f |

The values followed by the same letter on the same column are not significantly different (P > 0.05).

T0 = control; G11 = L. brevis G11; G25 = L. brevis G25; A6 = L. plantarum A6; M11 = L. buchneri M11; M41 = L. cellobiosus M41; L. fermentum N33; L. fermentum N25.
Fermentation time (hours)

| pH  | 0.0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2.5 |     |     |     |     |     |     |     |     |
| 3.0 |     |     |     |     |     |     |     |     |
| 3.5 |     |     |     |     |     |     |     |     |
| 4.0 |     |     |     |     |     |     |     |     |
| 4.5 |     |     |     |     |     |     |     |     |
| 5.0 |     |     |     |     |     |     |     |     |

**Figure 2:** Evolution of pH in the Kutukutu during fermentation by the various LAB at 25°C (T0 = control; G11 = *L. brevis* G11; G25 = *L. brevis* G25; A6 = *L. plantarum* A6; M11 = *L. buchneri* M1; M41 = *L. cellobiosus* M41; N33 = *L. fermentum* N33; N25 = *L. fermentum* N25).

with *L. buchneri* M11 after 48 h was observed. Contrarily to other LAB species, the reducing sugars were produced by *L. brevis* G25 over a long period (96 h). According to Osman [35], the increase of sugars during fermentation could be explained by the hydrolysis of starch due to amylases produced by the LAB. Osman [35] showed an increase of glucose in millet flour from 6.8 to 11.35 g/100 g after 20 h of fermentation at 30°C. Osman also portrayed an increase in fructose ranging from 1.17 to 1.20 g/100 g after 20 h of fermentation at 30°C. Reducing sugars can
equally be used during the fermentation by LAB for the synthesis of various organic acids [36]. This justifies the decrease of sugars in Kutukutu fermented with \( L. \) brevis G25 (304.9 to 131.5 mg/100 g DM) after 96 h and \( L. \) brevis G11 (282.9 to 246.3 mg/100 g DM), \( L. \) plantarum A6 (263.5 to 247.6 mg/100 g DM), \( L. \) buchneri (387.5 to 250.7 mg/100 g DM), \( L. \) cellobiosus (314.1 to 210.0 mg/100 g DM), \( L. \) fermentum N25 (321.7 to 236.1 mg/100 g DM), and \( L. \) fermentum N33 (353.9 to 215.7 mg/100 g DM) after 48 h. These results corroborate with those of Osman [35] who showed reduction of glucose and fructose from 11.35 to 7.3 g/100 g and 1.2 to 0.6/100 g, respectively, for fermented millet flour between 20 and 24 h.

3.4. Starch. The majority of starchy compounds in the Kutukutu decreased significantly \( (P < 0.05) \) during fermentation as compared to the control (Figure 4). After 120 h of fermentation, we observed reduction of starch ranging from 1213.9 to 3251.1 mg/100 g DM (73.2%) in the Kutukutu fermented with \( L. \) fermentum N33. The hydrolysis of starch by the LAB during fermentation reduces swelling of the starch granules and viscosity of the flours during the preparation of porridge [37]. The decrease of starch content in Kutukutu during fermentation could be due to the hydrolysis of starch due to amylases produced by the LAB into simple sugars [36]. Agati et al. [38] showed that LAB isolated from fermented maize could have a strong amyloytic activity. Hama et al. [39] showed a decrease of starch from 65.6 to 23.6 g/100 g (64.0%) after 72 h of spontaneous fermentation of Dégué.

3.5. Crude Proteins Content. A slight increase of the crude proteins content was observed during the fermentation of Kutukutu with all selected strains excepted for \( L. \) fermentum N33 (Figure 5). After 120 h of fermentation, crude proteins content in Kutukutu fermented with \( L. \) brevis G11, \( L. \) brevis G25, and \( L. \) cellobiosus M41 increased from 5.8 to 6.9 g/100 g DM (18.9%) for each one. However, \( L. \) fermentum N33 has a different behavior from the other bacteria. Initially, an increase in proteins content ranging from 5.8 to 6.3 g/100 g DM (8.6%) was observed after 48 h of fermentation, followed by a drop from 6.3 to 5.0 g/100 g DM (20%) after 120 h of fermentation.

The increase of crude proteins content could be attributed to the use of carbohydrates by LAB [35]. These results are in agreement with those of Awade et al. [40], who showed an increase in crude proteins content by 14.63% after 14 h of fermentation of corn flour.

However the decrease in proteins content observed in \( L. \) fermentum N33 fermented Kutukutu may be explained by the fact that the LAB used these proteins for their metabolic activities during fermentation [41]. Osman [35] observed a similar reduction of protein content by 4.5% after 20 h of fermentation of millet flour at 30°C.

3.6. Minerals Availability. During the fermentation of Kutukutu, a significant increase \( (P < 0.05) \) in minerals was observed (Table 2), but minerals content was different between all the tested bacteria strains. The highest content of Mg, Fe, and Na was registered in Kutukutu fermented with \( L. \) brevis G25 varying between 25.9 and 39 mg/100 g DM (50.5%), 9.2 and 15.7 mg/100 g DM (70.6%), and 1.2 and 1.3 mg/100 g DM (8.3%), respectively. There was also an increase in the K and P from 82.6 to 118.8 mg/100 g DM (43.8%) and from 95.1 to 138.1 mg/100 g DM (45.2%), respectively, in Kutukutu fermented with \( L. \) brevis G11. \( L. \) fermentum N33 and \( L. \) brevis G25 increased the Zn content in Kutukutu with values ranging from 1.1 to 1.3 mg/100 g DM (18.2%). \( L. \) brevis G25, \( L. \) brevis G11, and \( L. \) buchneri increased the Cu content in Kutukutu from 0.1 to 0.2 mg/100 g DM (100%), while only \( L. \) brevis G25 and \( L. \) brevis G11 increased the Mn content in Kutukutu from 0.2 to 0.4 mg/100 g DM (100%). The increment in minerals could be explained by the reduction of antinutritional substances such as phytates and phenolic compounds which form complexes with minerals [10, 42]. Eltayeb et al. [43] observed an increase of Fe and Zn from 5.8 to 5.9 mg/100 g and from 2.9 to 3 mg/100 g, respectively, in fermented millet flour of “Garira” variety after 24 h of spontaneous fermentation at 37°C. They also noticed an increase in P, Zn, and Fe content from 183.4 to 205.3 mg/100 g, 2.9 to 3.1 mg/100 g, and 6.5 to 10.2 mg/100 g, respectively, in the fermented millet flour variety “Gadarif” after 12 h of fermentation at 37°C [43].

3.7. Total Polyphenols. The evolution of total polyphenols content in Kutukutu during fermentation is shown in Figure 6. After 120 h of fermentation, the total polyphenols content was reduced from 425.8 to 66.3 mg/100 g DM (84.5%) and from 425.8 to 86.8 mg/100 g DM in the Kutukutu fermented with \( L. \) fermentum N33 and \( L. \) plantarum A6, respectively. The reduction in polyphenols content during fermentation could be attributed to the production of polyphenol oxidases by LAB [40]. Many studies on the improvement of nutritional quality of fermented grains such as millet showed a significant reduction of the levels of polyphenols [44, 45]. Adam et al. [46] observed a reduction in polyphenols content ranging from 120.4 to 111.08 mg/100 g and from 125.1 to 107.2 mg/100 g, respectively, in millet cultivar “Ugandi” and “Demi yellow” after 14 h of fermentation at 37°C.

3.8. Tannins. Tannins content was reduced significantly \( (P < 0.05) \) during the fermentation of Kutukutu compared to the control (Figure 7). \( L. \) plantarum A6 and \( L. \) fermentum N33 reduced the tannins content in Kutukutu from 215.1 to 2.5 mg/100 g DM (98.8%) and 215.1 to 4.6 mg/100 g DM (97.9%), respectively, after 120 h of fermentation. Indeed, some LAB such as \( L. \) plantarum, \( L. \) pentosus, and \( L. \) paraplan terum are able to degrade tannins through their acylhydrrolase tannin activity [47]. This ability is often associated with the vegetable products and confers an ecological advantageto the LAB [47]. Antony and Chandra [48] showed 52% reduction of tannins in millet flour during fermentation. In the same way Onyango et al. [49] reported a significant \( (P < 0.05) \) reduction of tannins content after 8 days of fermentation of red sorghum flour, white sorghum and millet at 25°C.
Table 2: Total minerals content in Kutukutu fermented with various LAB at 25°C after 120 h.

| LAB   | Time (hours) | Macronutrients (mg/100 g DM) | Micronutrients (mg/100 g DM) |
|-------|--------------|-------------------------------|-----------------------------|
|       |              | Ca   | Mg         | K   | Na   | P       | Zn   | Cu   | Mn   | Fe   |
|       | 0            | 1.2 ± 0.0 | 25.9 ± 0.1 | 82.6 ± 0.0 | 1.2 ± 0.0 | 95.1 ± 0.0 | 1.1 ± 0.0 | 0.1 ± 0.0 | 0.2 ± 0.0 | 9.2 ± 0.0 |
| G11   | 120          | 33.6 ± 0.4 | 118.9 ± 8.1 | 0.5 ± 0.1 | 138.1 ± 0.0 | 1.2 ± 0.0 | 0.2 ± 0.0 | 0.4 ± 0.0 | 12.9 ± 0.1 |
| G25   | 39.0 ± 2.2   | 102.1 ± 0.0bc | 1.3 ± 0.1c | 110.7 ± 0.0c | 1.3 ± 0.0b | 0.2 ± 0.0b | 0.4 ± 0.0c | 15.7 ± 0.0c |
| A6    | 33.8 ± 11.4d | 112.1 ± 0.6d | 0.8 ± 0.5b | 132.4 ± 0.1d | 1.2 ± 0.0bc | 0.1 ± 0.0c | 0.2 ± 0.0b | 12.4 ± 0.0d |
| M11   | 34.1 ± 11.4d | 106.6 ± 2.1bc | 0.5 ± 0.1a | 131.0 ± 1.0b | 1.1 ± 0.0bc | 0.2 ± 0.0b | 0.3 ± 0.0bc | 11.7 ± 0.1c |
| M41   | 31.7 ± 0.2c | 105.1 ± 0.1c | 0.4 ± 0.0a | 118.9 ± 0.1d | 1.0 ± 0.0a | 0.1 ± 0.0a | 0.2 ± 0.0c | 14.8 ± 0.0f |
| N25   | 31.1 ± 0.4c | 98.1 ± 0.1b | 0.8 ± 0.0b | 100.5 ± 0.5d | 1.2 ± 0.0d | 0.1 ± 0.0a | 0.1 ± 0.0a | 12.4 ± 0.0d |
| N33   | 28.0 ± 1.1b | 86.0 ± 0.0a | 0.8 ± 0.0b | 114.3 ± 0.6b | 1.3 ± 0.0f | 0.1 ± 0.0a | 0.1 ± 0.0a | 12.1 ± 0.0b |

The values followed by the same letter on the same column are not significantly different (P > 0.05).
3.9. Phytates. The entire selected LAB reduced the phytates content after 120 h of fermentation (Figure 8). Phytates content in *Kutukutu* fermented with *L. buchneri* M11 was reduced from 278.7 to 12.4 mg/100g DM (95.5%). This observed reduction of phytates can be due to phytases and phosphatases produced by LAB which hydrolyze phytates to inositol and orthophosphates [50]. Studies made by Ejigui et al. [50] also illustrated a reduction in phytates levels ranging from 9.87 to 3.8 mg/100 g in corn flour after 96 h of fermentation at 30°C. Similarly, Onyango et al. [49] reported a significant ($P < 0.05$) reduction of phytates in red sorghum flour, white sorghum, and millet after 8 days of fermentation at room
Figure 6: Evolution of total polyphenols in Kutukatu during fermentation by the various LAB at 25°C (T0 = control; G11 = L. brevis G11; G25 = L. brevis G25; A6 = L. plantarum A6; M11 = L. buchneri M1; M41 = L. cellobiosus M41; N33 = L. fermentum N33; N25 = L. fermentum N25).

Figure 7: Evolution of the tannin content in Kutukatu during fermentation by the various LAB at 25°C (T0 = control; G11 = L. brevis G11; G25 = L. brevis G25; A6 = L. plantarum A6; M11 = L. buchneri M1; M41 = L. cellobiosus M41; N33 = L. fermentum N33; N25 = L. fermentum N25).
The evolution of phytates content in Kutukutu during fermentation by the various LAB at 25°C (T0 = control; G11 = L. brevis G11; G25 = L. brevis G25; A6 = L. plantarum A6; M11 = L. b.uchneri M1; M41 = L. cellobiosus M41; N33 = L. fermentum N33; N25 = L. fermentum N25).

Figure 8: Evolution of phytates content in Kutukutu during fermentation by the various LAB at 25°C (T0 = control; G11 = L. brevis G11; G25 = L. brevis G25; A6 = L. plantarum A6; M11 = L. b.uchneri M1; M41 = L. cellobiosus M41; N33 = L. fermentum N33; N25 = L. fermentum N25).

Figure 9: Correlation circle of the variables of Kutukutu in the principal component analysis axis (TAN: tannins; PHY: phytates; POL: polyphenols; PROT: proteins, ACID: lactic acid; STRA: starch; SUG: sugar) analyzed during fermentation of Kutukutu by LAB.

This arrangement of variables and observations on F1 and F2 axis shows that L. fermentum N33 helps to reduce antinutrients factors such as phytates and polyphenols, while L. brevis G25 contributes to increased bioavailability of minerals (Mg, Mn, Cu, and Fe), lactic acid, and protein contents.
5. Conclusions

The fermentation of the Kutukutu by selected LAB induced many changes in nutritional properties as well as antinutritional factors. L. brevis G25 increased (80.7%) reducing sugars content and increased the proteins content to 18.9%. It also increases availability of Mg and Fe, respectively, to 50.5% and 70.6%. L. plantarum A6 reduced the tannins content to 98.8% in Kutukutu and L. buchneri M11 reduced the phytates content (95.5%) in the Kutukutu, while, for a best reduction of phytates and polyphenols, Kutukutu must be fermented by L. brevis G25. To improve protein content and minerals (Mg, Mn, Cu, and Fe), Kutukutu must be fermented by L. fermentum N33. Both of these bacteria can be used for improving the nutritional quality of Kutukutu during fermentation.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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