

Chapter

Assessment of the Nutritional Quality of Lactic Acid Bacteria Fermentation of Tiger Nut (*Cyperus esculentus*) Milk for Yogurt Production and Its Potential Health Benefits

*Stella Mojisola Adeyemo, Omolola Bosede Akinyemi,
Folake Titilayo Afolabi and Ayodele O. Olatimehin*

Abstract

Protein deficiency and malnutrition are on the rise among children of weaning age because protein sources are expensive for low-income earners. The regular supply of food crops is being threatened by drastic climate change, a lack of basic preservation methods, and susceptibility to microbial attack. This research focused on the production of yogurt from fresh tiger nut milk with a view to extending its shelf life and improving the nutritional quality of the starter-produced yogurt which can be used as weaning food. The yellow variety of tiger nut was obtained from local markets in Nigeria. They were sorted, cleaned, surface sterilized, milled, and sieved with a 45 μm mesh size to obtain the milk. The milk was pasteurized and fermented with lactic acid bacteria (LAB) that were isolated from "Ogi." The tiger nut and the yogurt were analyzed for physicochemical, nutritional, antinutritional, and organoleptic properties. There was an increase in (in mg/g) protein content (15.20), riboflavin (3.01), thiamine (4.19), and calcium (65), while a reduction in the antinutritional content was observed (in mg/100 g) (tannins 35 to 5; phytates 65 to 5). The shelf life of the yogurt was extended by the bio-preservative activity of LAB. The starter-mediated yogurt can solve the problem of malnutrition and lactose intolerance in infants.

Keywords: tiger nut milk, probiotics, nutritional quality, functional foods, gut health

1. Introduction

Tiger nut (*Cyperus esculentus*) is an underutilized crop of the family *Cyperaceae*; it produces rhizomes from the base and tubers that are somewhat spherical. The Hausa in Nigeria call it “Aya,” the Yorubas “Imumu,” the Igbos “Ofio,” and “Aki Hausa” in southern Nigeria. There are three varieties of tiger nut (black, brown, and yellow), but only the yellow and brown varieties are readily available in the market [1, 2].

Moreover, the yellow variety is preferred over other varieties because of its physical properties, such as its large size, attractive color and fleshier nature. It yields more milk, contains lower fat, and higher protein with fewer antinutritional factors, especially polyphenols [3]. About 80,000–100,000 tonnes of tiger nut are harvested in northern Nigeria annually [3]. Tiger nut has been cultivated as livestock feed and for human consumption; it can be eaten raw and may be roasted, grated, baked, or used for making ice cream and different types of beverages, making it very useful for different purposes with its attended benefits [4, 5].

According to Mason [6], tiger nuts have been shown to have many health benefits. First, they have a high content of soluble glucose and oleic acid with high energy content (such as starch, fats, sugars, and proteins). Secondly, they are very rich in minerals such as phosphorus, potassium, calcium, magnesium, and iron, which are necessary for the development of strong bones and muscles, repair of worn-out tissues, and the healthy flow and circulation of the bloodstream, as well as for body growth and development. They are a rich source of vitamins E and C. Tiger nuts have very low sugar content and, as such, are suitable for diabetic people and also help in weight control [7]. The carbohydrate content is based on sucrose and starch, with the absence of glucose. They also have a high content of arginine, which liberates the hormone that produces insulin. Tiger nuts provide digestive enzymes like catalase, lipase, and amylase, and they are recommended for those who suffer from indigestion, flatulence, and diarrhea, preventing constipation and reducing the risk of colon cancer. They have a high content of oleic acid, which activates soluble blood glucose, thereby reducing cholesterol, the risk of thrombosis, and heart attack [8]. They are rich in vitamin B1, which contributes to reducing stress and maintaining balance in the central nervous system [9]. The milk derived from tiger nuts supplies the body with enough quantity of vitamin E, which is essential for fertility in both men and women. It is also recommended for infants and the elderly because it has a high content of vitamin E and antioxidant benefits, which help delay cell aging by improving skin elasticity, the appearance of wrinkles, acne, and other skin alterations [5, 10].

Tiger nut milk is richer in iron, magnesium, and carbohydrates than cow's milk. It is also an ideal drink for people with lactose intolerance and those who show allergies to gluten or cow's milk. It can serve as an alternative to milk by meeting the increasing demand for milk and milk products. Additionally, it can serve as a cheap substitute for animal protein and also reduce zoonotic contamination.

It is commonly called “*kunnuaya*” in northern Nigeria, and it is a healthy drink with many nutrients. It is a rich source of vitamins C and E, as well as minerals such as phosphorus, magnesium, potassium, calcium, iron, and also carbohydrates, unsaturated fats, proteins, and some enzymes which help in digestion [5]. Nevertheless, the nutritional properties and shelf-life of tigernut milk can be enhanced through the process of fermentation, leading to the production of yogurt.

The fermentation of milk or dairy products by lactic acid bacteria (LAB), such as *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, is referred to as yogurt [11]. Yogurt has been an integral part of the everyday diet for centuries, and it is most popular among children from different ethnic groups around the world. The fermentation process results in the conversion of the milk sugar (lactose) to lactic acid by the LAB, and a change in physicochemical and rheological properties, which contributes to the unique taste and aroma of the product [12]. The organoleptic and textural properties, such as viscosity, smoothness, thickness [13], and structural resistance to stress, are important attributes that determine its consumer acceptance along with its attended health benefits. The sensory quality of yogurt has been improved upon, such as through the addition of fat and proteins to increase the solids in the milk, sugars such as sucrose and fructose, and the addition of pectin, starch, alginate, and gelatin as stabilizers [14].

With the recent awareness of consuming healthy, natural, and nutritious food and drink across the globe, the problem of artificial and chemical preservatives/sweeteners, along with their attended side effects, and the challenges associated with providing an adequate diet for weaning infants, this research is a concerted effort directed toward providing an alternative healthy drink in that regard. It may also serve as an alternative source of milk for those with lactose intolerance. The LAB demonstrated bio-preservative activity in the fresh tiger nut yogurt during the shelf-life monitoring of the product, and it is composed of a combination of natural sugars and bio-preservatives with no chemical or artificial additives. This study applied LAB from sorghum with good technological properties as a starter culture for the production of tiger nut yogurt with a view to extending the shelf life and improving the nutritional quality of the starter-produced tiger nut yogurt. It also discusses the health benefits of tiger nut yogurt.

Lactic acid bacteria (LAB) isolated from fermented foods are essential in enhancing the nutritional quality of fermented products because they effectively reduce major antinutritional factors through enzymatic activities such as phytase and tannase production, as well as acidification that promotes the breakdown of complex compounds [15, 16]. These mechanisms increase nutrient bioavailability, improving digestibility, protein utilization, and mineral absorption, while simultaneously lowering microbial load, enhancing shelf stability, and improving sensory attributes [17]. Equally important is the careful selection of robust starter cultures with strong survival capacity, acid tolerance, and the ability to maintain viability throughout processing and storage [18]. Evidence from probiotic dairy beverages demonstrates that well-chosen LAB strains not only support fermentation efficiency and product stability but also enhance the functional and health-promoting qualities of the final product [19]. Collectively, these insights highlight the dual importance of selecting appropriate starter cultures and leveraging LAB's natural detoxifying abilities to produce safe, nutritious, and consumer-acceptable fermented foods.

2. Materials and methods

Tiger nuts and *Sorghum bicolor* samples were purchased at Sabo Market, Ile-Ife, Osun State, Nigeria. *S. bicolor* grains were steeped in water for *ogi* production for five days to isolate LAB. The LAB was obtained and purified by successive sub culturing on MRS agar and subjected to biochemical tests. Gram-positive and

catalase-negative isolates were confirmed as LAB using their technological properties and antimicrobial activities.

2.1 Preparation of tigernut milk

Tiger nut tubers were sorted to separate the good ones from the bad ones. The clean and healthy nuts were milled to obtain the milk. The nuts were soaked overnight for approximately 12 hours, after which they were washed thoroughly and blended with water. The milk obtained was then filtered using muslin cloth, applying pressure to the contents to achieve maximum liquid extraction. The filtrate was put into a clean container and pasteurized for 15 minutes.

2.2 Spontaneous fermentation of tiger nut milk

The tiger nut milk was distributed in 100 mL portions in conical flasks, covered with aluminum foil, and left to undergo fermentation at room temperature ($28 \pm 2^\circ\text{C}$) for 72 hours.

2.3 Production of starter-mediated yogurt

LAB, which showed promise as good starters from an earlier study based on technological screening, were selected and applied. The selected LAB strains were *Lactobacillus plantarum* from sorghum *ogi* and *Lactobacillus fermentum* from commercially sold yogurt.

2.4 Inoculum preparation

The cell suspension of the two LAB candidates was prepared following the method described by Ozden [20]. Briefly, 10 mL of sterile normal saline was added to 18–24-hour methicillin-resistant *Staphylococcus aureus* (MRSA) slant cultures of the test LAB in a McCartney bottle and shaken to wash the cells in order to make a cell suspension. One milliliter of the cell suspension was aseptically transferred into 30 mL of sterile normal saline in a 100 mL capacity conical flask. The suspension was diluted to give an absorbance of 0.10 at 540 nm using a spectrophotometer, which was equivalent to 10^6 colony-forming unit (cfu)/mL.

2.5 Inoculation of pasteurized tiger nut milk for yogurt production

The pasteurized tiger nut milk (100 mL) in a conical flask was aseptically inoculated with 5 mL of the standardized cell suspension (5%) of the selected LAB as a single culture and then in combination to give a cell suspension of 10^6 of the milk [21]. The inoculated milk was left to ferment at 30°C for 24 hours. Samples were collected at intervals for microbiological and physicochemical analysis.

2.6 Starter culture production of yogurt

About 250 mL of pasteurized fresh tiger nut milk was inoculated with 12.5 mL (10^6 cfu/mL) of the selected organisms, followed by incubation at 30°C for 24 hours. Exactly 0.1 ml of appropriately diluted sample was spread-plated on De Man

Rogosa Sharpe (MRS) agar and incubated anaerobically in a candle jar at 30°C for 24 hours. After incubation, the plates were observed, and colonies were enumerated and expressed as cfu/mL of the milk.

2.7 Studies on the shelf life of spontaneous, starter-mediated and commercially sold yogurt

The freshly produced yogurt (traditional and starter-mediated) was stored at ambient temperature ($30 \pm 2^\circ\text{C}$) for seven days in sterile plastic containers with covers. During the storage period, samples were withdrawn for physicochemical analysis and viable microbial count at intervals of day 0, 3, 5, and 7 [22].

2.8 Evaluation of changes in the total bacteria count, coliforms, and fungi

The total bacteria count, coliform, and fungi count were determined following standard methods using nutrient agar, MacConkey agar, and potato dextrose agar, respectively. Exactly 1 mL of the yogurt sample was transferred into 9 mL of maximum recovery diluent (MRD) up to 10^{-8} and 0.1 mL of the appropriately diluted sample was spread-plated on nutrient agar, MacConkey agar, and potato dextrose agar for enumeration of total bacteria count, coliform, and fungi, respectively. The plates for viable and coliform counts were incubated at 37°C for 24 hours, and fungi plates were incubated at 25°C for 72 hours. After incubation, the plates were observed, and colonies were enumerated and expressed as cfu/mL for bacteria and selective forwarding unit (sfu)/mL for fungi.

2.9 Organoleptic analysis of spontaneous and starter mediated yogurt

The organoleptic properties of freshly produced traditional and starter-mediated yogurt were assessed by a panel of 50 regular consumers of yogurt. The samples were evaluated for color, taste, sourness, aroma, texture, and general acceptability on a 5-point hedonic scale, where 5 = like extremely, 4 = like, 3 = neither like nor dislike, 2 = dislike, and 1 = dislike extremely. The data obtained were subjected to analysis of variance.

2.10 Comparative studies of nutritional composition of raw tiger nut, spontaneous and starter-mediated yogurt

Raw tiger nuts and freshly produced yogurt prepared through spontaneous and starter-mediated fermentations, were subjected to proximate, mineral, and vitamin analysis.

2.10.1 Determination of proximate composition

Proximate parameters, such as protein, ash, fat, fiber, carbohydrate, and moisture content, were determined using standard procedures as described by Association of Official Analytical Chemists [23]. Minerals and vitamins were also determined using standard procedures.

2.10.2 Statistical analysis

The data obtained in this study were subjected to an analysis of variance and Duncan's multiple range test of variables using the SAS statistical software [22].

3. Results

The analysis of the proximate contents of the tiger nuts and yogurts produced from the tiger nut varies as shown in **Table 2**. The results revealed that the yogurt produced with *L. plantarum* (sample C) has the highest protein content (15.20), riboflavin (3.01), thiamine (4.19), and calcium content (65), while the highest fat (29), crude fiber (6.3), iron (5.4), and total sugar (10.2) were observed in sample A, with the least fat (0.76%) also in sample A. These constituents were significantly different ($p < 0.05$) from each other (see **Table 1**).

Vitamin composition, such as thiamine, riboflavin, niacin, calcium, and phosphate, was also analyzed for raw tiger nuts, spontaneous, starter culture-

Parameters(mg/g)	A	B	C	D	E
Moisture content	9.4 ± 0.02 ^a	55.2 ± 0.05 ^b	66.4 ± 0.00 ^b	68.4 ± 0.00 ^c	66.6 ± 0.01 ^b
Protein	6.6 ± 0.01 ^a	8.71 ± 0.09 ^b	15.2 ± 0.04 ^d	14.2 ± 0.02 ^c	12.1 ± 0.04 ^c
Ether extract	29 ± 0.08 ^b	17.4 ± 0.08 ^c	7.4 ± 0.02 ^a	7.7 ± 0.14 ^a	7.5 ± 0.06 ^a
Ash	3.7 ± 0.18 ^a	4.4 ± 0.06 ^a	8.3 ± 0.01 ^c	7.3 ± 0.22 ^b	7.4 ± 0.03 ^b
Carbohydrate	44.4 ± 0.4 ^c	60 ± 0.07 ^c	19.8 ± 0.08 ^a	21.8 ± 0.09 ^b	20.5 ± 0.01 ^b
Crude fiber	6.3 ± 0.01 ^c	0.3 ± 0.04 ^b	0.3 ± 0.05 ^b	0.3 ± 0.07 ^b	0.2 ± 0.08 ^a
Total sugars	10.2 ± 0.03 ^c	2.4 ± 0.03 ^a	1.7 ± 0.01 ^b	1.8 ± 0.08 ^b	2.5 ± 0.06 ^a

Values are the mean of three replicates ± standard deviation.

Samples – A: raw tiger nuts, B: yogurts produced from spontaneous fermentation, C: yogurts fermented with *L. plantarum*, D: yogurts fermented with *L. fermentum*, and E: commercially sold yogurt.

Table 1.

Proximate analysis of raw tiger nuts, spontaneous, starter culture-produced and commercially sold yogurts.

Parameters (mg/g)	A	B	C	D	E
Thiamine	0.19 ± 0.03 ^a	2.09 ± 0.07 ^b	4.19 ± 0.01 ^c	1.8 ± 0.03 ^b	1.4 ± 0.04 ^a
Riboflavin	0.09 ± 0.02 ^a	1.07 ± 0.09 ^a	3.01 ± 0.06 ^c	2.17 ± 0.2 ^b	2.0 ± 0.06 ^b
Niacin	1.6 ± 0.02 ^a	1.9 ± 0.00 ^b	1.9 ± 0.04 ^b	1.80 ± 0.04 ^b	1.9 ± 0.05 ^b
Ca ⁺⁺	5.5 ± 0.06 ^b	3.5 ± 0.04 ^a	6.5 ± 0.08 ^c	6.5 ± 0.01 ^c	6.0 ± 0.02 ^c
Iron	5.4 ± 0.04 ^b	4.9 ± 0.01 ^a	5.0 ± 0.02 ^b	4.9 ± 0.03 ^a	5.1 ± 0.09 ^b
Phosphate	9.5 ± 0.03 ^a	9.5 ± 0.08 ^a	9.8 ± 0.01 ^{a,b}	9.9 ± 0.05 ^b	9.7 ± 0.04 ^b

Values are the mean of three replicates ± standard deviation.

Samples – A: raw tiger nuts, B: yogurts produced from spontaneous fermentation, C: yogurts fermented with *L. plantarum*, D: yogurts fermented with *L. fermentum*, E: commercially sold yogurt.

Table 2.

Vitamins and mineral composition of raw tiger nuts, spontaneous, starter culture-produced and commercially sold yogurts.

Parameters(mg/100 g)	A	B	C	D
Saponins	ND	ND	ND	ND
Phytates	65 ± 0.00 ^c	25 ± 0.04 ^c	10 ± 0.02 ^b	5 ± 0.01 ^a
Protease inhibitor	0.3 ± 0.01 ^a	ND	ND	ND
Tanins	35 ± 0.02 ^b	5 ± 0.01 ^a	5 ± 0.02 ^a	5 ± 0.04 ^a

Values are the mean of three replicates ± standard deviation, ND: not detected.

Samples – A: raw tiger nuts; B: yogurts produced from spontaneous fermentation; C: yogurts fermented with *L. plantarum*; D: yogurts fermented with *L. fermentum*.

Table 3.

Antinutritional composition of raw tiger nuts, spontaneously and starter culture-produced yogurts.

produced, and commercially sold yogurts. The result is shown in **Table 2**. The antinutritional composition, such as saponins, phytates, protease inhibitors, and tannins, was determined for the raw tigernut, spontaneous, and starter culture-produced yogurts. Generally, starter culture-produced yogurt has less of these antinutritional compositions when compared to the raw tigernut. This is shown in **Table 3**.

Table 4 shows the results of the sensory properties evaluation of freshly prepared yogurt from spontaneous and starter culture fermentation. Sample A was rated best for all sensory evaluations, with the highest overall values. There was no significant difference ($p \leq 0.05$) in the aroma and appearance of all the sample B milk; however, the highest mean values for taste, texture, and general acceptance were observed in treatment C. For sample D milk, there was no significant difference ($p \leq 0.05$) in the aroma, appearance, and general acceptance, with D having the highest mean value for all the sensory attributes.

Table 5 shows the details of the microbiological monitoring of the shelf life. The results showed no observed growth of bacteria and fungi for all the yogurt on days 0 and 3, except for yogurt fermented spontaneously, which had a bacteria count of 6.06. Bacteria and fungi were also recorded on days 5 and 7 for the yogurt fermented with *L. plantarum* and spontaneously fermented yogurt, respectively. Coliforms were not observed or detected throughout the monitoring period.

Sample code	Colour	Taste	Aroma	Texture	General acceptability	Overall mean
A	4.47 ± 0.52 ^c	4.00 ± 0.65 ^a	4.27 ± 0.70 ^b	3.73 ± 1.49 ^a	4.40 ± 0.63 ^c	4.18 ± 0.53 ^b
B	3.27 ± 1.10 ^c	2.60 ± 0.83 ^b	2.87 ± 0.92 ^b	2.20 ± 0.94 ^a	2.67 ± 0.82 ^b	2.71 ± 0.35 ^b
C	4.20 ± 1.15 ^c	3.33 ± 0.90 ^a	3.47 ± 0.99 ^a	3.80 ± 0.86 ^b	3.20 ± 0.94 ^a	3.45 ± 0.51 ^a
D	4.50 ± 2.0 ^c	4.61 ± 1.0 ^c	4.30 ± 40 ^b	4.00 ± 10 ^a	4.35 ± 0.00 ^b	4.35 ± 00 ^b

Values are the mean of three replicates ± standard deviation.

Samples – A: yogurts produced from spontaneous fermentation, B: yogurts fermented with *L. plantarum*, C: yogurts fermented with *L. fermentum*, D: commercially sold yogurt.

Table 4.

Sensory evaluation of spontaneous, starter culture-produced and commercially sold yogurts.

Time (days)	A			B			C		
	Bacterial count Log (cfu/mL)	Coliform count Log (cfu/mL)	Fungal count Log (sfu/mL)	Bacterial count Log (cfu/mL)	Coliform count Log (cfu/mL)	Fungal count Log (sfu/mL)	Bacterial count Log (cfu/mL)	Coliform count Log (cfu/mL)	Fungal count Log (sfu/mL)
0	<10	ND	ND	<10	ND	ND	<10	ND	ND
3	3.30 ± 0.04 ^c	2.00 ± 0.03 ^b	1.00 ± 0.17 ^a	ND	ND	2.09 ± 0.03 ^b	<10	ND	3.80 ± 0.10 ^c
5	5.13 ± 0.02 ^c	3.04 ± 0.51 ^a	2.98 ± 0.21 ^a	2.50 ± 0.66 ^a	ND	4.00 ± 0.01 ^b	3.34 ± 0.41 ^a	2.34 ± 0.11 ^a	5.04 ± 0.50 ^c
7	7.19 ± 0.12 ^d	5.23 ± 0.18 ^c	5.43 ± 0.46 ^c	4.09 ± 0.09 ^b	2.12 ± 0.33 ^a	5.41 ± 0.08 ^c	5.94 ± 0.22 ^b	3.48 ± 0.34 ^b	6.23 ± 0.22 ^d

Values are the mean of three replicates ± standard deviation, $p \leq 0.05$.
Samples – A: yogurts produced from spontaneous fermentation; B: yogurts fermented with *L. plantarum*.

Table 5.

Microbiological quality of the spontaneous and starter-produced yogurt during storage.

3.1 Figures, tables, and schemes

4. Discussion

The protein content of starter culture-produced yogurt was high, with values of 15.20% and 14.20% for *L. plantarum* and *L. fermentum*, respectively. These values were above the minimum protein content of 3.5% for commercial yogurt [24]. The protein content is also higher than that of tiger nut, suggesting an increase in the nutritional components of the seed due to fermentation. The increase in the protein composition could be attributed to the concentration of the constituents during pasteurization, brought about by the loss of moisture and the reduction/destruction of certain protease and lipase inhibitors, which form complexes with protein and make them unavailable during hydrolysis. This was observed and reported as pasteurized fermented tiger nut milk notably reflected an increase in protein content. It was also observed that fermentation with starter culture increases thiamine, riboflavin, niacin, and calcium.

All starter-mediated yogurt had high moisture content between 66.4% and 68.4%. This could affect the stability and safety of yogurt with respect to microbial growth and proliferation; therefore, the product requires cold storage, in agreement with the work of Ukwuru and Ogbodo [25]. The result of the anti-nutrient component showed that raw tiger nut yogurt contained phytate and tannins. Saponins and protease inhibitors were not detected. It was noted that the values of phytate and tannins in the yogurts were below 1%. There was a reduction in the antinutritional composition of the fermented milk during fermentation due to the biotechnological activities of LAB. This implies that the product is very safe for consumption. Although this is not consistent with the result reported by Vieira-Dalodé et al. [26], who worked on the evaluation of the chemical composition of candy developed from tiger nut (*Cyperus esculentus*) milk, fermentation has been known to reduce antinutrients in food, thereby making the nutrients available.

Despite the significant difference in sensory quality of some fermented tiger nut milk, all the product samples were generally acceptable to the panelists. Similar works carried out on tiger nut milk [5, 27] recorded high acceptability of the milk. Although, from the figures obtained, little or no difference exists in all the sensory attributes between the samples, the level of acceptance of the tiger nut yogurt produced from the two starters and spontaneous fermentation is still very high.

The probiotic LAB have been shown to produce some antimicrobial properties, such as organic acids, hydrogen peroxide, and diacetyl, which are involved in extending the shelf life of yogurt. Chemical/artificial preservatives are usually frowned upon these days because of the associated allergies and side effects. Tiger nut yogurt has the advantage of containing natural preservatives produced by probiotic LAB; hence, our claim to use it as weaning food for infants. The shelf life of the product was extended by the bio-preservative activities of LAB.

The yogurt also contains natural sugars from the tiger nut; no artificial sweetener was added. It also contains natural flavors and no artificial flavoring agent was added. This justifies our effort toward providing an alternative source of protein for adults and children. The milk can be used as a source of supplement or fortification in carbohydrate weaning food. It is a rich source of protein in the diet, which can be used to combat protein malnutrition in children of weaning age. It can be mixed with *pap*, *ogi*, or any other cereal and can be consumed by those with lactose intolerance.

The selected starter cultures (*L. plantarum* [BM1] and *L. fermentum* [S12]) were able to reduce the antinutritional composition of the milk during fermentation and improve the nutritional composition of the yogurt while conferring bio-preservative properties on the tiger nut yogurt. The starters for the production of the yogurt were not only important but were also isolated (identified and confirmed) and obtained from cereals, possessing the biotechnological properties required for use as starters. Therefore, the research advances the field of food security and availability. The selected starter cultures (*L. plantarum* and *L. fermentum*) improved the nutritional composition of the fermented tiger nut yogurt and conferred bio-preservative properties on the yogurt due to their biotechnological properties. Yogurt fermented with cultures of *L. plantarum* showed the highest increase in nutritional composition and extended the shelf life of the yogurt through the antimicrobials it produced. It can be concluded that *L. plantarum* (BM1) is a suitable starter for the fermentation of tiger nut yogurt imparting desirable attributes to the product. Thus, the starter-culture-mediated yogurt can address the problem of malnutrition and lactose intolerance in weaning infants, and therefore, the research advances the field of food security, availability, and nutrition measurement.

4.1 The potential health benefits of tiger nut yogurt

Tiger nut (*Cyperus esculentus*) yogurt produced through LAB fermentation, combines the inherent nutritional richness of tiger nuts with the probiotic and bio-preservative advantages of microbial metabolism. This functional, plant-based yogurt offers multiple health-promoting properties that extend beyond its basic nutritional value, positioning it as a potential functional food for both dairy and non-dairy consumers.

4.2 Digestive health and gut microbiota balance

Fermentation with LAB, such as *Lactobacillus delbrueckii*, *Lactocaseibacillus rhamnosus*, and *S. thermophilus*, produces beneficial metabolites, including lactic acid and short-chain fatty acids, that promote intestinal health. These microorganisms modulate the gut microbiota, inhibit enteropathogens, and enhance mucosal integrity [15]. Regular consumption of tiger nut yogurt may improve bowel function, reduce diarrhea, and support the maintenance of a healthy gut microbiota [28, 29].

4.3 Lactose-free and hypoallergenic alternative

Tiger nut yogurt is entirely plant-based and naturally free from lactose and casein. It is suitable for individuals with lactose intolerance or milk protein allergies, as well as for vegans. Its smooth texture and pleasant flavor make it a nutritious alternative to dairy yogurt without eliciting allergic or intolerance reactions [16, 30].

4.4 Enhanced nutrient bioavailability

LAB fermentation enhances nutrient bioavailability by hydrolyzing complex carbohydrates and proteins, releasing bound micronutrients. Proteolytic activity of LAB improves protein digestibility, while microbial metabolism increases the availability of essential vitamins, including folate, niacin, and riboflavin. These transformations contribute to improved nutrient absorption and utilization [17, 31, 32].

4.5 Reduction of antinutritional factors

Tiger nuts contain phytates, tannins, and oxalates, which can limit mineral absorption and reduce protein digestibility. LAB fermentation significantly reduces these antinutritional compounds through microbial enzymatic activities, such as phytase and tannase production [18]. Studies have shown that *Lactobacillus*-fermented tiger nut milk exhibits marked decreases in phytate and tannin levels, thereby enhancing mineral bioavailability and improving nutritional efficiency [31, 33].

4.6 Antioxidant and anti-inflammatory properties

Fermentation liberates phenolic compounds and generates antioxidant peptides that help neutralize reactive oxygen species (ROS). These bioactive metabolites mitigate oxidative stress and inflammation, contributing to the prevention of degenerative diseases such as cardiovascular disorders and diabetes. LAB strains can also upregulate antioxidant enzyme expression and modulate inflammatory pathways [19, 34].

4.7 Cardiometabolic health benefits

Tiger nuts are rich in monounsaturated fatty acids, mainly oleic acid, which support heart health by reducing low-density lipoprotein (LDL) cholesterol and

improving lipid profiles. Fermentation can further lower the sugar content of tiger nut milk, yielding a product with a lower glycemic index suitable for diabetic and health-conscious consumers. The combined effects of bioactive lipids and LAB metabolism may thus contribute to improved cardiometabolic outcomes [15, 29].

4.8 Immune system support

Probiotic LAB strains stimulate immune responses by enhancing macrophage activity, cytokine secretion, and IgA production. These effects contribute to immune modulation, reduced susceptibility to infections, and improved systemic immunity. Regular intake of probiotic-rich tiger nut yogurt can, therefore, play a role in maintaining immune resilience [16, 28, 35].

4.9 Improved shelf life and food safety

LAB fermentation acts as a natural preservation method by lowering pH and producing bacteriocins and organic acids, which inhibit spoilage organisms and pathogens. The resulting product demonstrates extended shelf life and improved microbial safety, offering a clean-label alternative to chemically preserved beverages [17, 31, 32].

5. Summary

Lactic acid bacterial fermentation transforms tiger nut milk into a safe, nutritious, and functional yogurt analog. The process enhances the product's nutrient profile, reduces antinutritional factors, and introduces probiotic benefits that promote digestive, metabolic, and immune health. As a lactose-free and shelf-stable alternative, tiger nut yogurt holds strong potential for addressing nutritional deficiencies and expanding functional food options in both developed and developing regions. LAB play a multifaceted role in promoting human health by enhancing nutrient bioavailability through the reduction of antinutritional factors, exerting antimicrobial effects that inhibit food-borne and clinical pathogens, supporting gastrointestinal health and immune function as probiotics, and serving as natural bio-preservatives that extend the shelf life of food products without reliance on synthetic additives, while also offering therapeutic potential in combating infections associated with microorganisms and contaminated foods.

Patents

This work has been patented with Obafemi Awolowo University and the Federal Government of Nigeria under patent number NG/PT/NC/2019/3868.

Author Contributions

S.M.A.: conceptualization, resources, supervision, and funding acquisition;
S.M.A. and F.T.A.: methodology, writing – review and editing, and project

administration; O.A.A.: software; S.M.A. and O.B.A.: formal analysis and investigation; O.A.A. and O.B.A.: data curation; O.B.A.: writing – original draft preparation; S.M.A., F.T.A., and O.B.A.: visualization. All authors have read, validated, and agreed to the published version of the chapter.

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Author details

Stella Mojisola Adeyemo^{1*}, Omolola Bosede Akinyemi¹, Folake Titilayo Afolabi² and Ayodele O. Olatimehin¹

1 Microbiology Department, Obafemi Awolowo University, Ile-Ife, Nigeria

2 Microbiology Department, University of Ibadan, Ibadan, Nigeria

*Address all correspondence to: sadeyemo@oauife.edu.ng

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References

- [1] Adebayo-Oyetoro AO, Ogundipe OO, Adeyeye AO, Akande EA, Akinyele AB. Production and evaluation of tigernut (*Cyperus esculentus*) milk flavoured with Moringa olifera leaf extract. *Current Research in Nutrition and Food Science*. 2019;**10**:1–8
- [2] Adejuyitan Johnson. Tigernut Processing: Its Food uses and Health Benefits. *American Journal of Food Technology*. 2011;**6**. DOI: 10.3923/ajft.2011.197.201
- [3] Okafor JN, Mordi JI, Ozumba AU, Solomon HM, Olatunji O Preliminary studies on the characterization of contaminants in tiger nut (Yellow variety). In: *Proceedings of 27th Annual Conference in Nigeria Institute of Food Science Technology (NIFST)*; 13–17 October 2003; p. 210–211
- [4] Rita ES. The use of tiger nut (*Cyperus esculentus*), cow milk and their composite as substrate for yoghurt production. *Pakistan Journal of Nutrition*. 2009;**6**:755–758
- [5] Belew MA, Abodunrin OA. Preparation of kunnu from unexploited rich food source: Tigernut (*Cyperus esculentus*). *World Journal of Dairy and Food Sciences*. 2006;**1**:19–21
- [6] Mason D. Tiger nuts. Available from: http://www.nvsuk.org.uk/growing_show_vegetables [Accessed: 2018-June-26]
- [7] Martinez FAC, Balciunas EM, Converti A, Cotter PD, Souza Oliveira RPD. Bacteriocin production by *Bifidobacterium* spp: A review. *Biotechnology Advances*. 2013;**31**(4):482–488
- [8] Oguntoyinbo FA, Tourlomousis P, Gasson MJ, Narbad A. Analysis of bacterial communities of traditional fermented West African Cereal Foods using Culture Independent Methods. *International Journal of Food Microbiology*. 2011;**145**(1):205–210
- [9] Daeshel MA. Strains of *Lactobacillus plantarum* found in food from different cultures. *African Journal of Food and Nutritional Sciences*. 2004;**49**: 112–115
- [10] Ray RC, Kar S, Panda SK. Tiger nut (*Cyperus esculentus* L.) milk: A potential substitute for cow's milk for lactose-intolerant individuals. *Journal of Food Science and Technology*. 2004;**41**(1):1–4
- [11] Fontana L, Brito MB, Diaz JP, Quezada SM, Gil A. Sources, isolation, characterisation and evaluation of probiotics. *British Journal of Nutrition*. 2013;**109**:35–50
- [12] Purwandari U, Shah NP, Vasiljevic T. Effects of exopolysaccharide-producing strains of *Streptococcus thermophilus* on technological and rheological properties of set type yoghurt. *International Dairy Journal*. 2007;**17**(11):1344–1352
- [13] Jaworska D, Waszkiewicz-Robak B, Kolanowski W, Swiderski F. Relative importance of texture properties in the sensory quality and acceptance of natural yoghurts. *International Journal of Dairy Technology*. 2005;**58**(1):39–46
- [14] Behare PR, Singh SK, Tomar R, Nagpal M, Kumar Mohania D. Effect of exopolysaccharide-producing strains of *Streptococcus thermophilus* on

technological attributes of Fat Free Lassi. *Journal of Dairy Science*. 2010;**93**(7):2874–2879

[15] Adeyemo SM, Onilude AA, Olugbogi DO. Reduction of anti-nutritional factors of sorghum by lactic acid bacteria isolated from Abacha–An African Fermented Staple. *Frontiers in Science*. 2016;**6**(1):25–30

[16] Adeyemo SM, Afolabi FT, Ogunlusi ED. Therapeutic effect of lactic acid bacteria isolated from freshly-harvested honey and its comb against food and wound-borne pathogens. *International Journal of Probiotics and Prebiotics*. 2016;**11**(2):85–98

[17] Awojobi KO, Adeyemo SM, Sanusi OO. Biosynthesis of antimicrobial compounds by lactic acid bacteria and its use as bio-preservative in pineapple juice. *Frontiers in Science*. 2016;**6**(1):17–24

[18] Adeyemo SM, Afolabi FT, Awojobi KO, Abiri TO. Probiotic effects of lactic acid bacteria and its use as bio-preservative for tomatoes juice and paste. *International Journal of Probiotics and Prebiotics*. 2017;**12**(1):99–116

[19] Adeyemo SM, Agun TF, Ogunlusi ED. Antimicrobial activity of lactic acid bacteria isolated from Pupuru: An African Fermented Staple against food-borne pathogens. *Journal of Molecular Biology and Biotechnology*. 2018;**3**:1–5

[20] Ozden A. Other fermented dairy products: Bioyoghurt-probiotic yoghurt. *Guncel Gastroenteroloji*. 2008;**12**(3):169–181

[21] Shah NP. Probiotic bacteria: Selective enumeration and survival in

dairy foods. *Journal of Dairy Science*. 2000;**83**(4):894–907

[22] Shinde PB. Probiotic: An overview for selection and evaluation. *International Journal of Pharmacy and Pharmaceutical Sciences*. 2012;**4**:14–21

[23] AOAC. Official Methods of Analysis. Washington D.C: Association of Official Analytical Chemists; 2010

[24] Cleveland J, Montville TJ, Nes IF, Chikindas ML. Bacteriocins: Safe, natural antimicrobials for food preservation. *International Journal of Food Microbiology*. 2001;**71**:1–20

[25] Ukwuru MU, Ogbodo AC. Effect of processing treatment on the quality of Tiger Nut Milk. *Pakistan Journal of Nutrition*. 2011;**10**:95–100

[26] Vieira-Dalodé G, Jespersen L, Hounhouigan DJ, Moller PL, Nago CM, Jakobsen M. Lactic acid bacteria and yeasts associated with Gowé production from sorghum in Bénin. *Journal of Applied Microbiology*. 2007;**103**(2):342–349

[27] Ukwuru MU, Omachona LJ, Onokah N. Production and quality assessment of Tiger Nut (*Cyperus esculentus*) imitation milk during storage. *Journal of Food Science and Technology*. 2008;**45**:180–182

[28] Arora M, Kaur N, Bansal P, Baldi A. Therapeutic Potential of Probiotics: A Ray of Hope or Nightmare? *Applied Clinical Research, Clinical Trials and Regulatory Affairs*. 2019. DOI: 10.2174/2213476X06666190126161931

[29] Shah NP. Functional cultures and health benefits. *International Dairy Journal*. 2017;**73**:1–13

[30] Agrawal R. Probiotics and lactose intolerance. *Indian Journal of Medical Research*. 2005;**122**(1):13–24

[31] Adeyemo SM, Onilude AA. Enzymatic Reduction of Anti-nutritional Factors in Fermenting Soybeans by *Lactobacillus plantarum* Isolates from Fermenting Cereals. *Nigerian Food Journal*. 2013;**31**(2):84–90. DOI: 10.1016/S0189-7241(15)30080-1

[32] Widyastuti Y, Rohmatussolihat, Febrisiantosa A. The role of lactic acid bacteria in milk fermentation. *Food and Nutrition Sciences*. 2014;**5**:435–442

[33] Adeyemo SM, Onilude AA. Reduction of oligosaccharide content of soybeans by the action of *Lactobacillus plantarum* isolated from fermented cereals. *African Journal of Biotechnology*. 2014;**13**(37):3790–3796. DOI: 10.5897/AJB2013.13398

[34] Donkor ON, Henriksson A, Singh TK, Vasiljevic T, Shah NP. ACE-Inhibitory activity of probiotic yoghurt. *Journal of Dairy Science*. 2007;**90**(8):3738–3746

[35] FAO/WHO. Probiotics in food: Health and nutritional properties and guidelines for evaluation (FAO Food and Nutrition Paper No. 85). Food and Agriculture Organization of the United Nations. <https://www.fao.org/3/a0512e/a0512e.pdf>