Journal homepage: www.scienceletters.researchfloor.org

Contents list available at Journal of e-Science Letters

Journal of e-Science Letters

Original Research Article | ISSN :3041-5454

Extraction and Utilization of Colorants From Tea Leaf Fibre in The Formulation of Shelf-Stable Local Beverages

Luntsi John*[1], Peter Michael Dass[2], Bingong Ishaku Hamidu[1], and Oboyi Matthew Echeofun[1]

[1] *Department of Chemical Sciences, Faculty of Science, PMB: 1167, Taraba state University, Jalingo, Nigeria*
[2] *Department of Chemistry, Modibbo Adama University, PMB: 2076, Yola, Adamawa State, Nigeria*

ABSTRACT

This study investigated the utilization of waste Tea Leaf Fibre Extract (TLFE) as a natural colorants and functional additive in the formulation of three indigenous Nigerian beverages: Kunu-zaki, Tiger Nut Milk, and Ginger Extract. The primary objective was to assess the impact of TLFE on the sensory properties, physicochemical stability, alcoholic content, and microbial quality of these composite beverages, thereby promoting the reuse of agricultural waste. TLFE was obtained using three methods: Infusion, Maceration, and Soxhlet. The Soxhlet extraction method proved to be the most efficient, yielding the highest percentage (26.42 %), compared to Maceration (21.92 %) and Infusion (12.75 %). Three optimized beverage composites were subjected to comprehensive quality assessments. Sensory analysis, conducted using a 9-point hedonic scale, indicated a distinct consumer preference for the TLFE-Tiger Nut Milk (TL-TN) composite, which consistently received the highest mean scores for Overall Acceptability, Aroma, Flavour, and Smoothness. Conversely, the TN-TL composite was the least favored. Microbiological assays showed that all control beverages had microbial loads in the 10^5 CFU/mL range, except for Ginger, which showed "No growth" due to inherent antimicrobial properties. The composites showed variability, with high bacterial counts in the Tiger Nut Milk-TLFE (9.0×10^6 CFU/mL at 1:1) and Ginger-TLFE (19.1×10^6 CFU/mL at 1:5) variants, indicating potential spoilage issues at these ratios. Critically, the Ginger-TLFE 5:1 ratio proved to be the most microbiologically stable formulation, resulting in "No growth," confirming the potent inhibitory effect of high ginger concentration. Furthermore, all formulated beverages were classified as non-alcoholic, exhibiting very low Alcohol by Volume (ABV) content ranging from 0.06 % to a maximum of 0.88 %. Alcohol production correlated positively with the proportion of the base ingredient (fermentable sugars) and was reduced when TLFE acted as a diluent. The findings demonstrate that TLFE successfully serves as a functional colorant and stabilizing agent, supporting the development of novel, quality-enhanced, and microbiologically stable indigenous beverages, particularly highlighting the potential of the TL-TN blend for sensory appeal and the Ginger-TLFE 5:1 blend for enhanced shelf-life.

Keywords: *Tea Leaf Fibre Extract (TLFE), Natural Colorant, Kunu-zaki, Tiger Nut Milk, Ginger Beverage, Food Stability, Antimicrobial Activity, Alcohol by Volume (ABV), Soxhlet Extraction, Sensory Evaluation.*

1. INTRODUCTION

Tea (Camellia sinensis) leaves yield extracts rich in polyphenols (10-13%) and caffeine (2-4%) [9; 34], known for strong antioxidant properties and diverse human health benefits [13]. The specific chemical profile varies with cultivar and processing [34; 27].

Citation: Luntsi John, Peter Michael Dass, Bingong Ishaku Hamidu, Oboyi Matthew Echeofun (2025). Extraction and Utilization of Colorants From Tea Leaf Fibre in The Formulation of Shelf-Stable Local Beverages. *Journal of e-Science Letters.*
DOI: https://doi.org/10.51470/eSL.2025.6.4.73

Received: 12 September 2025
Revised: 23 October 2025
Accepted: 18 November 2025
Available: December 09 2025

Corresponding Authors: **Luntsi John**
Email: **luntsijohn@gmail.com**

The global scale of tea production results in massive quantities of spent tea leaf (STL) or spent tea fibre (TF) as a by-product. Nigeria is a medium tea producer, generating significant tea processing waste that is often indiscriminately dumped or incinerated, leading to environmental and economic hazards [15; 28]. Despite this waste, spent tea fibre remains a valuable resource, containing lignin (dietary fibre) [11] and polyphenols with demonstrated antioxidant and antimicrobial activities [29].

Simultaneously, traditional Nigerian beverages like Kunu-zaki (Kunu) and Tiger nut milk suffer from poor stability and limited shelf life due to rapid microbial fermentation, resulting in quality degradation (color/taste changes) and potential health risks [4; 2]. Addressing these spoilage issues often requires natural additives, which are gaining renewed interest over synthetic alternatives due to safety concerns and a global shift toward renewable, non-toxic formulations [34].

Investigate the potential of the spent tea by-product (STL/TF) as a novel, functional additive for extending the shelf life and enhancing the sensory and nutritional quality of locally consumed Nigerian beverages. We specifically demonstrate that incorporating the bioactive components from tea waste improves the stability and color characteristics of Kunu, Tiger nut milk and Ginger, providing an effective waste-valorization strategy to mitigate environmental issues while addressing critical food quality concerns.

2. Materials and Methods

2.1 Sample Collection and Treatment

Tea leaf fibre (TLF) or tea fibre (TF) was obtained from Mambila Beverages Production Company located in Kakara, Taraba State, Nigeria. The collected Mambila tea leaf fibre samples underwent oven drying at a temperature of overnight to decrease moisture levels. The dried fibre was subsequently ground into a fine powder and sieved with a mesh of 20 µm.

2.2 Determination of Moisture Content

A moisture content assessment was performed on the powdered tea fibres. Five grams of the sample (5 g) was weighed, dried in the oven for 30 minutes at 150 ^{0}C, allowed to cool in a desiccator, and weighed multiple times until consistent weights were attained. The ground samples were then stored in labelled brown envelopes for later use in the extraction of colorants [5;8].

2.3 Extraction Techniques for Colorants from Tea Leaf Fibre

120 grams of the fine powdered tea leaf fibres were used for each extraction method.

2.3.1 Soxhlet Method

A sample of 120 g of the finely ground tea leaf fibres was placed in a thimble within a soxhlet extractor. In this process, methanol was vaporized, condensed, and cycled back into the sample chamber, facilitating the extraction of the desired compounds [10]. Following extraction, the mixture was filtered through muslin cloth and the extract was then subjected to evaporation using a water bath with the resulting residue then utilized for phytochemical analysis.

2.3.2 Maceration Method

To extract the fine powder of tea leaf fibre, the maceration technique was used. This involved adding 120 grams of fine powdered tea leaf fibre into a 1000 mL beaker and covering it with water as the menstruum. The container was sealed and left for a minimum of three days, during which it was stirred occasionally to ensure thorough extraction [7]. After three days, it was filtered through muslin cloth and the extract was then subjected to evaporation using a water bath. The yield of the extract was subsequently measured and noted.

2.3.3 Infusion Method

The extraction of the fine powdered tea leaf Fibres was carried out using the infusion method. In this process, 120 grams of the fine powder was steeped in 260 mL of hot boiling water within a 1000 mL beaker. The mixture stood in hot water for about five minutes before being filtered through muslin cloth and then Whatman No. 1 filter paper. The clear filtrate was then concentrated using a water bath set at 60 ^{o}C. The yield of the extract was subsequently measured and noted [23].

2.4 Purification of the Extracts

The Soxhlet, Maceration, and Infusion extracts were filtered through a muslin cloth and then, the extracts were filtered through a Whatman No. 1 filter paper to remove particulate matter and impurities.

2.5 Color Stability Evaluation

To assess the color stability of the beverage, a three-pronged approach was used. First, visual evaluation was conducted using photography to capture and document any changes over time. The beverage samples were then stored under different conditions: room temperature, refrigeration, and direct sunlight to simulate various storage environments. Finally, to track any chemical changes that might affect color, regular observations and pH measurements were taken every 24 hours [30].

2.6 Application and Evaluation of the Extracted Colorants in Local Beverages

2.6.1 Preparation of Kunu Beverage

Sorghum grains and sugar were obtained from Sangere supermarket and cleaned before being soaked in water. The method of preparation was a modification of the traditional method. After thorough washing, about 500 g of the washed sorghum grain were soaked in water at room temperature. The soaked grain was washed and wet milled together with spices. Following wet sieving, the mixture underwent partial gelatinization. The final product was sweetened with sugar and packaged [1]. Kunu sorghum beverage samples were created in the Department of Chemistry at Modibbo Adama University of Yola, Nigeria.

2.6.2 Tiger Nut Beverage (Kunu Aya)

Tiger nut seeds, fresh ginger, coconut, dates, and sugar were bought from a local supermarket in Sangere for making the Kunu-aya beverage. To create Kunu-aya or Tigernut nut milk, it involves removing nut nodules after which a cleaning, washing and sorted tiger nut seeds were soaked in water for 5 hours, then they were wet milled together with preferred spices and filtered using muslin cloth to get the milk-like supernatant which is the tiger nut milk (TNM) [3]. The resultant slurry was bottled and chilled for further analysis.

2.6.3 Ginger Beverage

Fresh ginger and sugar were sourced from the Sangere local supermarket in Yola. About 500 g of fresh ginger roots were thoroughly washed and peeled, then chopped into smaller segments. This ginger was blended with hot water; the resulting mixture was filtered through cheesecloth to collect the ginger extract or juice. It was sweetened with sugar, bottled and chilled for further analysis.

2.6.4 Optimization of the Local Beverage Composite

The optimization of the composite local beverage for each base ingredient (Kunu Sorghum, Tiger Nut Milk, Ginger Extract) with the Tea Leaf Fibre Extract (TLFE) was formulated through a two-stage approach: Varying the ratio of tea leaf fibres extract to base beverage; The TLFE ratio was progressively increased relative to the base (1:1, 2:1, 3:1, 4:1, and 5:1). Varying the ratio of base beverage to tea leaf fibres extract: Base beverage ratio was progressively increasing relative to TLFE (1:1, 1:2, 1:3, 1:4, and 1:5) [26]. All composite samples were prepared in the Department of Chemistry at Modibbo Adama University, Yola, Nigeria, using traditional techniques.

2.7 pH Measurements of Extracted Colorants and the Formulated Beverages

The pH of the drinks was determined using a pH meter. 20 mL of the drinks were measured into a beaker, and the pH was determined after the meter was calibrated using standard buffers of pH 4.00 and 6.86.

Sufficient time was allowed for stabilization before readings were taken [6].

2.8 Alcoholic Content Analysis of the Beverages

To determine the alcoholic content of the beverages, the Brix values were measured both before (Original Brix) and after (Final Brix) fermentation. The difference between these two values was then used to calculate the percentage of alcohol by volume (%) using a specific formula. The change in Brix is an indicator of the amount of sugar consumed by yeast, which directly correlates to the alcohol produced.
The standard formula to estimate Alcohol by Volume (ABV) from the initial and final Brix measurements is: [14;33].

2.9 Microbial Analysis of Beverage Samples

2.9.1 Preparations of Nutrient Agar (NA)

To prepare nutrient agar, 28 g of nutrient agar powder was dissolved in 1000 mL of distilled water. The mixture was covered and heated on a bunsen burner, boiling it until completely dissolved. The solution was sterilized in an autoclave at 120 ^{0}C for 15 minutes. The agar was allowed to cool approximately at 45 ^{0}C before aseptically pouring it into Petri dishes [16].

2.9.2 Pour Plate Method

Using a standard pour plate method, 0.1 mL of the diluted samples was aseptically transferred to separate, labelled plates containing nutrient agar. The plates were then incubated at 37 ^{0}C for 24 hours to allow for microbial growth. Microbial colonies were counted at the end of the incubation period and recorded [12].

2.10 Sensory Evaluation of the three Formulated Local Beverage Composite

The sensory evaluation of the experiment optimized local beverages (Kunu Sorghum Tea, Tiger Nuts Tea, Ginger Tea Beverage samples) was analyzed using a 9-point hedonic scale, with the degree of likeness of the product attribute expressed as: 1- dislike extremely, 2- dislike very much, 3- dislike moderately, 4- dislike slightly, 5- neither like nor dislike, 6- like slightly, 7- like moderately, 8- like very much and 9- like extremely [25].

3. Results

3.1 Comparison of Extraction Yields

Table 1: Comparison of yields from Different extraction Techniques

Extraction techniques Weight of Loss of Weight Extraction Yield samples (g) (g) (%)
Infusion Method 120 15.3 12.75
Maceration Method 120 26.3 21.92
Soxhlet Extraction Method 120 31.7 26.42

3.2 Optimized Alcoholic Content of Beverages

Table 2: Optimized alcoholic content of Kunu-tea leaf fibre extract beverages

S/N	Sample Ratios (Base:TLFE)	Original Brix	Final Brix	Alcohol by Volume (%)
1	Kunu – TLFE 1:1	3.40	2.80	0.33
2	Kunu – TLFE 1:2	2.15	2.04	0.061
3	Kunu – TLFE 1:3	1.69	1.35	0.187
4	Kunu – TLFE 1:4	1.49	1.22	0.149
5	Kunu – TLFE 1:5	1.09	0.97	0.066
6	Kunu – TLFE 1:1	3.40	2.80	0.33
7	Kunu – TLFE 2:1	5.02	4.70	0.176
8	Kunu – TLFE 3:1	5.57	4.82	0.413
9	Kunu – TLFE 4:1	5.93	5.11	0.451
10	Kunu – TLFE 5:1	6.57	5.35	0.671

Table 3: Optimized alcoholic content of Tiger Nut Milk-tea leaf fibre extract beverages

S/N	Sample Ratios (Base:TLFE)	Original Brix	Final Brix	Alcohol by Volume (%)
1	Tiger NM – TLFE 1:1	1.44	0.95	0.269
2	Tiger NM – TLFE 1:2	1.20	0.81	0.215
3	Tiger NM – TLFE 1:3	1.06	0.73	0.182
4	Tiger NM – TLFE 1:4	0.90	0.62	0.154
5	Tiger NM – TLFE 1:5	0.73	0.40	0.182
6	Tiger NM – TLFE 1:1	1.44	0.95	0.269
7	Tiger NM – TLFE 2:1	5.29	4.51	0.429
8	Tiger NM – TLFE 3:1	5.47	4.62	0.468
9	Tiger NM – TLFE 4:1	6.20	4.99	0.666
10	Tiger NM – TLFE 5:1	6.67	5.10	0.864

Table 4: Optimized alcoholic content of Ginger-tea leaf fibre extract beverages

S/N	Sample Ratios (Base:TLFE)	Original Brix	Final Brix	Alcohol by Volume (%)
1	Ginger – TLFE 1:1	1.74	1.04	0.385
2	Ginger – TLFE 1:2	1.20	1.01	0.105
3	Ginger – TLFE 1:3	1.97	0.56	0.776
4	Ginger – TLFE 1:4	0.81	0.64	0.105
5	Ginger – TLFE 1:5	0.76	0.51	0.138
6	Ginger – TLFE 1:1	1.74	1.04	0.385
7	Ginger – TLFE 2:1	2.03	0.71	0.726
8	Ginger – TLFE 3:1	2.48	1.07	0.776
9	Ginger – TLFE 4:1	2.84	1.25	0.875
10	Ginger – TLFE 5:1	2.94	1.38	0.858

3.3 Microbial Analysis

3.3.1 Control Beverages

Table 5: Microbial analysis of tea, Kunu sorghum, Tiger Nut milk, and Ginger beverages serving as controls

S/N	Sample	Frequency Bacteria	Colony Forming/mL
1	Tea only	15	1.5×10^5
2	Kunu only	17	1.7×10^5
3	Tiger Nut milk only	19	1.9×10^5
4	Ginger only	-	-

3.3.2 Optimized Composites

Table 6: Optimized microbial analysis of Kunu-tea leaf fibre extract beverages

S/N	Sample Ratios (Base:TLFE)	Frequency Bacteria	Colony Forming/mL
1	Kunu-TlFE 1:1	7	7.0×10^5
2	Kunu-TlFE 1:2	5	5.0×10^5
3	Kunu-TlFE 1:3	4	4.0×10^5
4	Kunu-TlFE 1:4	4	4.0×10^5
5	Kunu-TlFE 1:5	4	4.0×10^5
6	Kunu-TlFE 1:1	7	7.0×10^5
7	Kunu-TlFE 2:1	5	5.0×10^5
8	Kunu-TlFE 3:1	4	4.0×10^5
9	Kunu-TlFE 4:1	4	4.0×10^5
10	Kunu-TlFE 5:1	4	4.0×10^5

Table 7: Optimized microbial analysis of Tiger Nut Milk-tea leaf fibre extract beverages

S/N	Sample Ratios (Base:TLFE)	Frequency Bacteria	Colony Forming/mL
1	Tiger nut milk - TLFE 1:1	90	9.0×10^6
2	Tiger nut milk - TLFE 1:2	5	5.0×10^5
3	Tiger nut milk - TLFE 1:3	3	3.0×10^5
4	Tiger nut milk - TLFE 1:4	28	2.8×10^5
5	Tiger nut milk - TLFE 1:5	21	2.1×10^6
6	Tiger nut milk - TLFE 1:1	20	2.0×10^6
7	Tiger nut milk - TLFE 2:1	25	2.5×10^5
8	Tiger nut milk - TLFE 3:1	4	4.0×10^5
9	Tiger nut milk - TLFE 4:1	3	3.0×10^5
10	Tiger nut milk - TLFE 5:1	30	3.0×10^6

Table 8: Optimized microbial analysis of Ginger-tea leaf fibre extract beverages

S/N	Sample Ratios (Base:TLFE)	Frequency Bacteria	Colony Forming/mL
1	Ginger - TLFE 1:1	51	5.1×10^6
2	Ginger - TLFE 1:2	50	5.0×10^6
3	Ginger - TLFE 1:3	45	4.5×10^6
4	Ginger - TLFE 1:4	30	3.0×10^6
5	Ginger - TLFE 1:5	194	19.1×10^6
6	Ginger - TLFE 1:1	51	5.1×10^6
7	Ginger - TLFE 2:1	3	3.0×10^5
8	Ginger - TLFE 3:1	7	$7.0 x10^5$
9	Ginger - TLFE 4:1	13	1.3×10^6
10	Ginger - TLFE 5:1	No growth	-

3.4 Sensory Evaluation

Key:

- TL-KS: Tea leaf fibre extract-Kunu Sorghum at (1:1)
- KS-TL: Kunu Sorghum-Tea leaf fibre extract at (1:1)
- TL-TN: Tea leaf fibre extract-Tiger nuts milk at (1:2)
- TN-TL: Tiger Nuts milk -Tea leaf fibre extract at (3:1)
- TL-GE: Tea leaf extract-Ginger extract at (1:3)
- GE-TL: Ginger Extract-Tea leaf extract at (3:1) *(Scale: 1 = Dislike Extremely to 9 = Like Extremely)*

Table 9: Sensory analysis of beverages: Mean responses from panel of 20 Assessors

Sensory Attribute	TL-KS	KS-TL	TL-TN	TN-TL	TL-GE	GE-TL
Aroma	7	6	8	5	7	6
Appearance	8	7	9	6	8	7
Color	6	5	7	6	8	5
Flavour	7	8	9	5	6	7
Sweetness	5	6	7	4	5	6
Sourness	4	3	5	6	4	3
Smoothness	8	7	9	5	6	7
Overall Acceptability	7	6	8	5	7	6

Mean and Mean Deviation Calculation for Each Sensory Coded Local Beverages

Mean: (Equation 1) Mean Deviation: (Equation 2) Where = number of data values (20), = data values in the set, = average value of the data set.

Table 10: Mean and mean deviation evaluation for coded drinks

Sensory Attribute	TL-KS	KS-TL	TL-TN	TN-TL	TL-GE	GE-TL
Mean	6.5	5.875	7.625	5.125	6.25	5.625
Mean Deviation	1.25	1.5	1.25	0.875	1.25	1.25

4. Discussion

Generally, Soxhlet extraction produces higher yield percentages (26.42%) when compared to Maceration (21.92%) and Infusion (12.75%) (Table 1). This is mainly because soxhlet extraction is a more automated and efficient method, allowing continuous cycling of solvents that aids in extracting more compounds from finely ground tea leaf fibres. In contrast, Maceration and Infusion depend on slower and milder extraction methods, which might lead to lower yields. Nevertheless, these techniques can still work well for extracting specific compounds, especially those that are sensitive to heat or strong solvents. The extract from tea leaf fibres appeared dark brown to black. This coloration could result from the oxidation process that black tea experiences during its production, giving it its typical dark hue. The extract maintains this deep color, leading to a rich, brown-black appearance. Regarding the efficiency of Soxhlet extraction, our finding is in supported by other research; for instance, the reported yield from the Soxhlet extraction of crude Curcumin from Tumeric usin ethyl alcohol as a solvent was 10.23 % [17].

Tables 2, 3, and 4 show the alcoholic content analysis for the Kunu-TLFE, Tiger Nut Milk-TLFE, and Ginger-TLFE beverages, respectively. The results consistently show that the alcoholic content increases as the ratio of the base traditional beverage (Kunu, Tiger Nut Milk, or Ginger) increases relative to the Tea Leaf Fibre Extract (TLFE). This is because the primary ingredients are the sources of fermentable sugars. The generally higher ABV in the Ginger-TLFE samples could be attributed to the possibility of fermentable carbohydrates in ginger or its inherent compounds that aid in sugar breakdown.

The alcohol content in all samples is very low, ranging from approximately 0.06% to 0.88%. This means that despite undergoing fermentation, all the beverages would be legally classified as non-alcoholic. The Tea Leaf Fibre Extract (TLFE), likely a non-fermentable component, appears to dilute the sugar content, leading to lower alcohol production when it is present in higher proportions (e.g., 1:5 ratio). This suggests that the production process did not involve a controlled, high-yield fermentation but rather a spontaneous and limited one [20;19;24].

Table 5 shows that the control beverages (Tea, Kunu Sorghum, Tiger Nut Milk, and Ginger) were analyzed to establish a baseline microbial load before blending with the TLFE. The TVBC for the control beverages was all in the 10^5 CFU/mL range, except ginger which showed "No growth", which serves as the reference for evaluating the effect of the TLFE incorporation in the composite blends. Tables 6, 7, 8 show the optimized composite beverages were analyzed across various mixing ratios of the Base beverage to Tea Leaf Fibre Extract (Base: TLFE) to assess the impact of TLFE on the microbial count. Table 6 shows that the TVBC for the Kunu-TLFE composites was generally higher than the Kunu control, primarily in the 4.0×10^5 to 7.0×10^5 CFU/mL range. The highest count was observed in the Kunu-TLFE 1:1 ratio, reaching 7.0×10^5 CFU/mL. A notable reduction in bacterial count was observed as the ratio shifted away from 1:1 (both base-rich and TLFE-rich ratios), with 4.0×10^5 CFU/mL being the lowest count observed in ratios 1:3, 1:4, 1:5, 3:1, 4:1, and 5:1. This suggests that high concentrations of either the *K*unu base or the TLFE may contribute to a marginal preservative or inhibitory effect relative to the 1:1 mix.

Table 7 shows the microbial counts for the Tiger Nut Milk-TLFE composites showed the most significant variation, ranging from 3.0×10^5 to 9.0×10^6 CFU/mL. The Tiger Nut Milk-TLFE 1:1 ratio displayed an exceptionally high TVBC of 9.0×10^6 CFU/mL, indicating a potential synergistic effect that promoted bacterial growth or a contamination event. The lowest TVBCs were 3.0 to 10^5 CFU/mL, observed at 1:3 and 4:1 ratios. The higher counts in this composite, especially 9.0×10^6 CFU/mL (S/N 1), 2.1×10^6 CFU/mL (S/N 5), 2.0×10^6 CFU/mL (S/N 6), and 3.0×10^6 CFU/mL (S/N 10), warrant particular attention as they significantly exceed the baseline and the counts in other composites, potentially indicating a greater susceptibility to spoilage or contamination.

Table 8 shows that the TVBC for the Ginger-TLFE composites ranged significantly from "No growth" to 19.1×10^6 CFU/mL. The highest count, 19.1×10^6 CFU/mL, was recorded for the TLFE-rich ratio 1:5 (Base:TLFE), which is the maximum TVBC observed across all samples. This high value suggests the combination in this ratio is highly conducive to bacterial proliferation. Conversely, the Base-rich ratio 5:1 resulted in "No growth", indicating a potent inhibitory of this specific combination. Other ratios showed TVBCs in the 3.0×10^5 to 7.0×10^5 CFU/mL range, which are relatively lower, suggesting the antimicrobial components of ginger exert a protective effect in most combinations. The findings of this research aligned with those reported in the study by [16] ('Proximate, Mineral and Microbial Analysis of Locally Produced Juice (Kunu, Soymilk and Tigernut)'), particularly regarding the high microbial loads found in these types of beverages.

The sensory characteristics of the optimized composite drinks (TL-KS, KS-TL, TL-TN, TN-TL, TL-GE, and GE-TL) were evaluated by a panel of 20 assessors using a hedonic scale (based on the score range, assumed 1-9). The analysis covered key attributes including Aroma, Appearance, Color, Flavour, Sweetness, Sourness, Smoothness, and Overall Acceptability.

The initial perception of the beverages was significantly driven by TL-TN (Tea Leaf Fibre Extract-Tiger Nut Milk), which received the highest mean scores for both Aroma and Appearance. Conversely, TN-TL (Tiger Nut Milk-Tea Leaf Fibre Extract) was rated lowest for both attributes. This trend emphasizes the critical role of these visual and olfactory attributes in initial acceptance. For Color, TL-GE (TLFE-Ginger) was highly preferred, while KS-TL (Kunu Sorghum-TLFE) and GE-TL (Ginger-TLFE) received the lowest scores, suggesting that the specific color imparted by these combinations was less appealing to the panel.

Flavour, considered a critical factor in overall acceptability, was also maximized in TL-TN, which obtained the highest mean score. TN-TL simultaneously received the lowest mean score, indicating a significant dislike for its specific flavour profile. In terms of Sweetness, the most preferred level was found in TL-TN, while the least preferred was in TN-TL, suggesting the optimal balance of sweetness for the panel was achieved in the TL-TN formulation. For Sourness, TL-TN was rated highest, indicating that a certain level of tanginess was appreciated by some assessors. However, the lowest scores for sourness in KS-TL and GE-TL suggest a general preference for less sour beverages.

The mouth feel, evaluated as smoothness, followed the established pattern, with TL-TN receiving the highest score for a pleasant texture, and TN-TL the lowest. The consistently high scores across all attributes culminated in TL-TN being rated the most preferred drink overall, with the highest mean score for Overall Acceptability. In stark contrast, TN-TL was the least favored, indicating a failure to meet panel expectations across multiple sensory parameters. This result establishes that a combination of favorable aroma, appearance, flavour, and smoothness directly and significantly contributes to the overall acceptance of a beverage.

The observed degree of likeness for flavour, sourness, and overall acceptability, ranging from 5.00–9.00, 3.00–6.00, and 5.00–8.00 respectively, aligns with the findings of [25] on a *Hibiscus sabdariffa* drink, where similar likeness scores for flavour (5.45–7.75), sourness (5.05–7.55), and overall acceptability (5.66–7.51) were reported. These scores generally signify a range of acceptance from "neither like nor dislike" to "like moderately" or "like very much" (depending on the scale interpretation). Furthermore, the likeness ranges obtained for sweetness (4.00–7.00) and smoothness (5.00–8.00) in this study are also consistent with the ranges reported in the previous investigation. This similarity suggests that the consumer preference for sweetness, flavour, and textural attributes is relatively consistent across different fruit and plant-based beverages.

5. Conclusion

The Soxhlet extraction method proved to be the most efficient for obtaining TLFE, yielding the highest percentage (26.42%) compared to Maceration (21.92%) and Infusion (12.75%), primarily due to its automated, continuous cycling of solvent. All composite beverages were classified as non-alcoholic, with very low Alcohol by Volume (ABV) content ranging from 0.06 % to 0.88. The ABV increased with a higher proportion of the base traditional beverage (Kunu, Tiger Nut Milk, or Ginger), which supplies fermentable sugars. The TLFE acted as a diluent, reducing alcohol production when present in higher ratios. The base beverages exhibited microbial loads in the 10^5 CFU/mL range, with Ginger being the sole control showing "No growth" due to inherent antimicrobial properties. The microbial analysis of the composites showed significant variability, with some ratios, particularly in the Tiger Nut Milk-TLFE (1:1 ratio, 9.0×10^6 CFU/mL) and Ginger-TLFE (1:5 ratio, 19.1×10^6 CFU/mL) composites, showing high bacterial counts, indicating high susceptibility to spoilage. The Base-rich Ginger-TLFE 5:1 ratio proved to be the most microbiologically stable formulation, resulting in "No growth," confirming the potent inhibitory effect of high ginger concentration. The TL-TN (Tea Leaf Fibre Extract-Tiger Nut Milk) composite emerged as the most preferred beverage overall, consistently receiving the highest mean scores for Aroma, Appearance, Flavour, Sweetness, and Smoothness. Conversely, the TN-TL (Tiger Nut Milk-Tea Leaf Fibre Extract) composite was the least favored across all attributes. The results demonstrate that Overall Acceptability is highly dependent on a synergistic combination of favorable sensory attributes, with the TL-TN formulation achieving the optimal balance for consumer preference.

References

1. Adeyemi, A., & Umar, S. (2004). Effects of methods of manufacture on quality characteristics of Kunun Zaki, a millet-based beverage. *Nigerian Food Journal, 13*, 24–26.
2. Abaejoh, R., Djomdi, I., & Ndojouenkeu, R. (2006). Characteristics of tigernut (*Cyperus esculentus*) tubers and their performance in the production of a milky drink. *Journal of Food Processing and Preservation, 30*, 145–163.
3. Akoma, O., Elekwa, U. O., Afodurinbi, T. T., & Onyeukwu, G. C. (2020). Yoghurt from coconut and tigernuts. *Journal of Food Technology in Africa, 5*, 132–134. https://www.ajol.info/index.php/jfta/article/view/19270
4. Akoma, O., Jiya, E. A., Akunmka, D. D., & Mshila, E. (2006). Influence of malting on the nutritional characteristics of kunun-zaki. *African Journal of Biotechnology, 5*(10), 996–1000.
5. AOAC. (2002). *Official methods of analysis* (16th ed.). Association of Official Analytical Chemists.
6. AOAC. (2012). *Official methods of analysis of the Association of Analytical Chemists* (19th ed.). AOAC International.
7. Azwanida, N. N. (2015). A review on the extraction methods used in medicinal plants: Principle, strength and limitation. *Medicinal & Aromatic Plants, 4*(196).
8. Babayemi, O. J., Demeyer, D., & Fievez, V. (2004). In vitro rumen fermentation of tropical browse seeds in relation to their content of secondary metabolites. *Journal of Animal and Feed Sciences, 13*, 31–34.
9. Balentine, D. A., Wiseman, S. A., & Bouwens, L. C. (1997). The chemistry of tea flavonoids. *Critical Reviews in Food Science and Nutrition, 37*(8), 693–704.
10. Bozinou, E., Karageorgou, I., Batra, G., Dourtoglou, V. G., & Lalas, S. I. (2019). Pulsed electric field extraction and antioxidant activity determination of *Moringa oleifera* dry leaves: A comparative study with other extraction techniques. *Beverages, 5*(1), 8.
11. Bunzel, M., & Ralph, J. (2006). NMR characterization of lignins isolated from fruit and vegetable insoluble dietary fiber. *Journal of Agricultural and Food Chemistry, 54*(21), 8352–
12. Cheesbrough, M. (2002). *Biochemical tests to identify bacteria*. In *Laboratory practices in tropical countries* (pp. 63–87). Cambridge University Press.
13. Das, P. R., & Eun, J. B. (2018). A comparative study of ultrasonication and agitation extraction techniques on bioactive metabolites of green tea extract. *Food Chemistry, 253*, 22–29.
14. Dinello, N. (2024). From Saint Nino to women in Georgia's winemaking. *Caucasus Journal of Social Sciences, 17*(1), 29–46.
15. Fievez, V., Babayemi, O. J., & Demeyer, D. (2005). Estimation of direct and indirect gas production in syringes: A tool to estimate short chain fatty acid production that requires minimal laboratory facilities. *Animal Feed Science and Technology, 123*, 197–210.
16. Frances, E. C., Enoch, N. N., Johnson, O. O., Eziamaka, A. E., & Ann, M. O. (2023). Proximate, mineral and microbial analysis of locally produced juice (Kunu, soymilk and tigernut). *Asian Journal of Food Research and Nutrition, 2*(3), 36–47.
17. Himesh, S., Sharan, P. S., Mishra, K., Govind, N., & Singhai, A. K. (2011). Qualitative and quantitative profile of curcumin from ethanolic extract of *Curcuma longa*. *International Research Journal of Pharmacy, 2*(4), 180–184.
18. Khan, N., & Mukhtar, H. (2018). Tea and health: Studies in humans. *Current Pharmaceutical Design, 24*(44), 5275–5285.
19. Li, S., Liu, X., Wang, L., Wang, K., Li, M., Wang, X., ... & Wang, Z. (2024). Innovative beverage creation through symbiotic microbial communities inspired by traditional fermented beverages: Current status, challenges and future directions. *Critical Reviews in Food Science and Nutrition, 64*(28), 10456–10483.

20. Maicas, S., & Mateo, J. J. (2023). The life of *Saccharomyces* and non-*Saccharomyces* yeasts in drinking wine. *Microorganisms, 11*(5), 1178.
21. Martins, N., Roriz, C. L., Morales, P., Barros, L., & Ferreira, I. C. F. R. (2017). Coloring attributes of betalains: A key emphasis on stability and future applications. *Food & Function, 8*, 1357–1372.
22. Nath, D. (2019). Isolation and characterization of caffeine from *Camellia sinensis* collected from Eastern Himalayan region of India. *Biomedical European Journal* (May issue).
23. Nn, A. (2015). A review on the extraction methods used in medicinal plants: Principle, strength, and limitation. *Medicinal & Aromatic Plants, 4*(1), 3–8.
24. Nwaiwu, O., Aduba, C. C., Igbokwe, V. C., Sam, C. E., & Ukwuru, M. U. (2020). Traditional and artisanal beverages in Nigeria: Microbial diversity and safety issues. *Beverages, 6*(3), 53.
25. Obinna-Echem, P. C., & Cookey, F. I. (2022). Physicochemical properties of *Hibiscus sabdariffa* drinks in different packaging materials during ambient and refrigeration storage. *International Journal of Food Science and Nutrition, 7*(3), 170–178.
26. Olufunke, A., & Oluremi, K. O. (2015). Assessment of nutritional and sensory quality of Zaki-A home-made traditional Nigerian beverage. *Journal of Nutrition and Food Sciences*, *5*(3), 5-8.
27. Rains, T. M., Agarwal, S., & Maki, K. C. (2011). Anti-obesity effects of green tea catechins: A mechanistic review. *The Journal of Nutritional Biochemistry, 22*(1), 1–7.
28. Tea Board of India. (n.d.). https://www.teaboard.gov.in
29. Sakagami, H., Kawazoe, Y., Komatsu, N., Simpson, A., Nonoyama, M., Konno, K., ... & Tanuma, S. (1991). Antitumor, antiviral and immunopotentiating activities of pine cone extracts: Potential medicinal efficacy of natural and synthetic lignin-related materials. *Anticancer Research, 11*(2), 881–888.
30. Sikorski, Z. E., Pokorny, J., & Damodaran, S. (2007). Physical and chemical interactions of components in food systems. In *Fennema's food chemistry* (pp. 861–896). CRC Press.
31. Srinivasan, K. (2017). Ginger rhizomes (*Zingiber officinale*): A spice with multiple health beneficial potentials. *PharmaNutrition, 5*(1), 18–28.
32. Vasala, P. A. (2012). Ginger. In K. V. Peter (Ed.), *Handbook of herbs and spices* (Vol. 1, pp. 195–206). Woodhead Publishing.
33. Vinci, G., & Maddaloni, L. (2020). Biogenic amines in alcohol-free beverages. *Beverages, 6*(1), 17.
34. Yang, C. S., Wang, X., Lu, G., & Picinich, S. C. (2009). Cancer prevention by tea: Animal studies, molecular mechanisms and human relevance. *Nature Reviews Cancer, 9*(6), 429–439.
35. Zakaria, M. H. N., Eanamul, M. A. M., Hasan, M. Y., Abu, A., Ramjan, R., Lutfor, M. M., & Raza, M. (2017). Dyeing of S/J cotton knit fabric with natural dye extracts from green walnut shells: Assessment of mordanting effect on fastness properties. *Journal of Textile Science and Technology, 3*, 17–30.