DOI: https://doi.org/10.4038/tare.v28i1.5736

Tropical Agricultural Research & Extension 28 (1): 2025

RESEARCH ARTICLE

FORMULATION AND ANALYSIS OF READY TO SERVE BEVERAGE UTILIZING NELLI (*Phyllanthus emblica*) AND BANANA PSEUDOSTEM JUICE

Jeyarajasingam AA, Pushparaja V , Vasantharuba S*

Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna, Kilinochchi, Sri Lanka

Received: 01 August 2024; Accepted: 20 January 2025; Published: 31 March 2025

ABSTRACT

The banana fruit industry produces pseudostems as by-products, which are often regarded as waste. However, these pseudostems are rich in minerals, fibers, and other nutrients, making them a valuable resource for enhancing the therapeutic and nutritional value of food products. *Nelli*, recognized for its medicinal benefits in traditional medicine, often sees a surplus of ripe fruits going to waste during peak seasons. Therefore, this study aims to formulate and standardize a healthy, therapeutic ready-to-serve (RTS) beverage by blending different proportions of banana pseudostem and Nelli juice: T1 (100:0), T2 (80:20), T3 (60:40), T4 (40:60) and T5 (20:80). Sensory evaluation was conducted using a 5-point hedonic scale, revealing that T3 received significantly higher ($p < 0.05$) preference compared to the other treatments. Subsequently, the physicochemical properties, proximate composition and antioxidant properties of raw materials, T1 and T3 were evaluated. The study highlighted that RTS beverages incorporating banana pseudostem juice (T3) retained significant amounts of crude fiber, flavonoids and antioxidant capacity. Shelf-life studies conducted over two months confirmed the stability of final products, with microbial counts remaining within acceptable limits. Therefore, this research highlights the potential of these RTS beverages as nutritious options utilizing sustainable agricultural products.

Keywords: Antioxidant, Banana pseudostem, *Nelli* juice, Ready-to-serve beverage

INTRODUCTION

Banana is the second-largest cash crop in the world, with more than 100 million tons of annual production. Approximately 60% of the banana biomass is wasted after harvest and post-processing. It has been stated that for every ton of banana fruit harvested, around 3 tons of pseudostem, 150 kg of rachis, and 480 kg of leaves are discarded, contributing to environmental hazards (Pillai *et al*., 2024). However, these discarded biomasses are abundant in phosphorus, calcium, magnesium and potassium sources. Furthermore, the presence of advantageous bioactive compounds needed in the human diet like alkaloids, amino acids (L-tryptophan, phenylalanine, L-lysine, and L-glutamic acid), derivatives of lipids (α-linolenic acid and palmitoleic acid), flavonoids, nucleotides (guanosine, adenine) and other organic acids are also seen (Deng *et al*., 2020).

Moreover, banana pseudostems have shown remarkable medicinal properties due to the presence of essential biomolecules . They are rich in beneficial compounds such as tannins and pectin, which possess anthelminthic and sedative effects (Ravi *et al*., 2011). Additionally, the banana pseudostem is a valuable source of potassium and vitamins, playing a crucial role in insulin and hemoglobin synthesis while also helping to maintain electrolyte and fluid balance in the body (Swarnalakshmi *et al*., 2019). The antioxidants, fibers, micronutrients and macronutrients found in the banana pseudostem are highly beneficial, supporting the management of conditions like high blood pressure diabetes and obesity (Mydhili *et al*., 2022). Fresh juice from the banana pseudostem is suggested for consumption to

Corresponding author: seeva@univ.jfn.ac.lk

cleanse and detox the body. It also helps to prevent kidney stones, epilepsy, dysentery, and diarrhoea. Due to its high medicinal value, the banana pseudostem is highly recommended in Ayurveda and Unani medicine for its effectiveness against infectious and degenerative diseases; however, current estimates indicate that only 2% are being utilized (Pillai *et al*., 2024).

Nelli, an underutilized fruit in Sri Lanka, possesses rich medicinal properties utilized extensively in Ayurvedic medicine (Kulkarani *et al*., 2017). It exhibits anabolic, antiemetic, astringent, antihemorrhagic, antidiarrheal, diuretic, antidiabetic and carminative properties (Dasaroju and Gottumukkala, 2014). Fresh *Nelli* fruit is an excellent source of vitamin C (470 to 600 mg per 100 g) and along with essential minerals such as Ca, P, Fe, and carotene (Srivasuki, 2012). Furthermore, the phenolic compounds and flavonoids present in *Nelli* fruit have significant potential as bioactive agents in medicine. These compounds possess antioxidant properties and may aid in the prevention and treatment of various diseases (Ikram *et al*., 2021). Given its medicinal benefits, *Nelli* is also an excellent ingredient for formulating RTS beverages (Meena *et al*., 2017).

RTS beverages are popular for all ages due to their refreshing nature and taste. In recent years, there has been a growing interest in fruit -based drinks enriched with nutritious ingredients as dietary supplements. Functional beverages, a distinct category, are gaining popularity due to their focus on health and wellness. As consumers become more health-conscious, they increasingly seek drinks that provide multiple benefits. With the rising demand for soft drinks, there is significant potential to develop value-added beverages that incorporate nutrient-rich foods with medicinal properties (Vilas-Boas *et al*., 2022).

On this basis, the current research aimed to enhance the utilization of the underutilized banana pseudostem and *Nelli* fruit by creating a distinctive RTS beverage that combines their juices. This value-added product can serve as a superior alternative for enhancing consumer health by leveraging the medicinal properties of these ingredients while effectively utilizing banana pseudostem and *Nelli* fruits. Further, this can reduce the environmental issues caused by unutilized banana pseudostems.

MATERIALS AND METHODS

The research was conducted at the Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna, Sri Lanka. Disease-free and fresh banana (*Kolikuttu* variety) pseudo stems and *Nelli* fruits were collected from a local farm in Jaffna, Sri Lanka. The banana pseudostems were collected in a fully mature stage and immediately after the harvesting of banana fruits. The pseudo stems and *Nelli* fruits were chopped into small pieces, blended and filtered using a muslin cloth to obtain *Nelli* juice and pseudostem juice. These juices were then stored under refrigerated conditions (5 ° C) for future use.

Additional ingredients, such as sugar, edible-grade citric acid, and potassium metabisulfite (KMS), were purchased from the local market, Sri Lanka.

Formulation of the ready-to-serve drink.

The RTS drink was prepared in five different formulations by incorporating different ratios of banana pseudostem juice into the *Nelli* juice, following the procedure outlined by Bornare and Sumaiya (2015). The formulations were as follows:

Treatment 1 (Control -T1) - 0% of Banana pseudostem juice + 100% of *Nelli* juice
Treatment 2 (T2) - 20% of Banana pseudostem juice + 80% of *Nelli* juice
Treatment 3 (T3) - 40% of Banana pseudostem juice + 60% of *Nelli* juice
Treatment 4 (T4) - 60% of Banana pseudostem juice + 40% of *Nelli* juice
Treatment 5 (T5) - 80% of Banana pseudostem juice + 20% of *Nelli* juice

The calculated amount of sugar and citric acid was added to each treatment to maintain a constant 10° Brix and 0.3% acidity. Then, 50 ppm KMS was added for each treatment. Replicates of each treatment were formulated and kept in a refrigerator (5° C) for further analysis.

Sensory evaluation
The sensory analysis of RTS drink samples was conducted to evaluate their sensorial qualities: appearance, color, flavor, astringency, odor and overall acceptability. A panel of 35 semi-trained panelists were instructed to record their observations using a 5-point hedonic scale (Naseeha *et al*., 2023).

Physiochemical analysis
The pH was measured using a digital pH meter, while total soluble solids (TSS) were determined with a hand refractometer and expressed as °Brix. The titratable acidity of various samples was determined by titration against 0.1 N NaOH following the AOAC (2000) method. All measurements were taken for triplicated samples (Nilugin and Mahendran, 2010).

Proximate analysis
The moisture, crude protein, crude fat and ash contents were determined for triplicated samples using the methods described by AOAC (2000). Crude fiber analysis was conducted using an ANKOM 200 Fiber Analyzer. The total carbohydrate content was calculated by adding the amounts of moisture, ash, crude fiber, crude fat and crude protein in the sample and subtracting this amount from 100% (Godswill, 2019).

Estimation of reducing sugar and total sugar
The DNS method was used to determine the reduced sugar and total sugar contents of RTS beverages as described by Saqib and Whitney (2011). The experiment was conducted for triplicated samples.

Estimation of antioxidant properties
The antioxidant properties of the samples were analyzed by determining their total phenolic content, total flavonoid content and antioxidant capacity for triplicated samples. Total phenolic content was determined using the Folin-Ciocalteu method with absorbance readings taken at 760 nm. In contrast, total flavonoid content was determined using the Aluminum chloride colorimetric method, and absorbance was measured at 510 nm (Godswill, 2019). The antioxidant capacity of the samples was determined using the DPPH free radical scavenging assay, following the method described by Phuyal *et al*. (2020). Absorbance readings were taken at 517 nm to quantify the antioxidant activity.

Microbial analysis
Microbial analysis was conducted for triplicated samples after 30 and 60 days of storage period. Total plate counts were determined using the method described by Mailoa *et al*. (2017), and Yeast and mold counts were assessed following the procedure outlined by Saeed *et al*. (2019).

Statistical analysis
Sensory evaluation results were statistically analyzed using SPSS statistics with a 95% confidence interval. The statistical analysis of other quality parameters was performed using the SAS statistical package, and mean separation was performed for all quality parameters using Duncan's Multiple Range Test (DMRT) at the 5% level of significance (Rittisak *et al*., 2023; Sewwandi *et al*., 2020).

RESULTS AND DISCUSSION

Sensory analysis results of developed RTS beverages
The Table 1 presents the mean values of sensory attributes analyzed for RTS beverages formulated with varying proportions of banana pseudostem juice and *Nelli* juice. According to the sensory analysis, the T3 formulation showed superior sensory attributes compared to other formulations. Conversely, the T1 sample consistently showed the lowest scores across these attributes. This indicates that the addition of *Nelli* juice, known for its sour and astringent taste profile, positively influenced the overall sensory perception of the formulated drinks (Goraya and Bajwa, 2015). Significant differences were observed among the samples for most sensory attributes, except for color ($p < 0.05$). The incorporation of banana pseudostem juice enriched the beverage with nutrients and contributed to enhanced flavor and taste, as highlighted by previous studies (Goraya and Bajwa, 2015; Shiva *et al*., 2018). Overall, the findings suggest that blending banana pseudostem juice with *Nelli* juice in

varying ratios enhances the sensory quality of the RTS beverages.

Table 1: Mean values of sensory evaluation.

Sensory attribute	T1	T2	T3	T4	T5
Appearance	3.26±1.11^{a}	3.37±0.66^{a}	4.57±0.67^{c}	3.9±1.12^{b}	4.00±1.08^{b}
Odor	2.90±0.92^{a}	3.27±0.69^{ab}	4.03±0.85^{c}	3.57±1.07^{bc}	3.63±1.00^{bc}
Astringency	2.43±0.94^{a}	3.13±0.89^{b}	3.93±0.58^{c}	3.60±1.16^{bc}	3.67±1.15^{c}
Flavor	2.37±0.81^{a}	3.23±0.97^{b}	4.23±0.99^{c}	3.73±0.83^{b}	3.47±1.07^{b}
Color	3.30±0.99^{a}	3.50±1.19^{ab}	3.97±0.80^{c}	3.60±1.10^{ab}	3.63±0.89^{ab}
Sweetness	2.17±1.12^{a}	3.17±1.01^{b}	3.97±1.24^{c}	3.53±1.22^{bc}	3.57±1.33^{bc}
Overall acceptability	2.30±0.92^{a}	3.30±0.95^{b}	4.02±0.92^{c}	3.50±1.28^{bc}	3.73±1.23^{bc}

Mean±SD values in each row superscripted by different letters (a - c) were significantly different at $p < 0.05$

Physicochemical properties of raw materials and RTS beverages.

The physicochemical properties of the raw materials and RTS beverages are detailed in Table 2. The pH of *Nelli* juice was measured as 3.13, comparable to the 3.00 reported by Kumar *et al*. (2017), but significantly higher than ($p < 0.05$) the 1.97 noted by Kulkarani *et al*. (2017). In contrast, the pH of raw banana pseudostem juice was 5.57, exceeding the 4.9 reported by Bornare and Sumaiya (2015). These variations can be attributed to differences in the maturation stage, environmental conditions and variety of the fruits. According to the literature, the relatively low pH values of both juices can reduce the risk of microbial spoilage and enzymatic activity, which is crucial for maintaining food quality (Surya *et al*., 2020).

Table 2: Physico-chemical properties of raw materials and RTS beverages

Properties	Raw materials		RTS beverages	
	Nelli	Banana pseu-dostem	T1	T3
Titratable acidity (%)	2.25 ±0.21	0.13 ±0.01	0.32 ±0.01^{a}	0.30 ±0.04^{a}
pH	3.13 ±0.16	5.57 ±0.20	3.22 ±0.08^{a}	3.99 ±0.31^{b}
TSS (%)	11.33 ± 0.57	2.33 ±0.57	10.00 ± 0.00^{a}	10.00 ±0.00^{a}
Total sugar (%)	24.41 ± 1.27	48.36 ±1.05	10.25 ± 0.02^{b}	8.65 ±1.02^{a}
Reducing sugar (%)	14.07 ± 1.43	3.03 ±0.05	19.35 ± 0.08^{a}	28.12 ±0.85^{b}

Mean±SD values of RTS beverages in each row with different super-scripts (a – b) have significant differences at $p < 0.05$

Total soluble solids (TSS) content in *Nelli* juice was 11%, aligning with the 9-15% range reported by Meena *et al*. (2017). However, this measurement contrasts with the TSS values of 7%, 12.7% and 8.1% reported by Survase *et al*. (2018), Kulkarani *et al*. (2017) and Kumar *et al*. (2017), respectively. For banana pseudostem juice, the value of TSS was 2.33%, closely resembling the 2.9% reported by Saravanan and Aradhya (2011), but lower than the 4% indicated by Bornare and Sumaiya (2015). Environmental conditions and fruit maturity during harvesting time may influence this variation.

The acidity of food products, typically expressed as a percentage of anhydrous citric acid, is a crucial factor influencing consumer acceptance and is considered a significant characteristic of RTS beverages. The titratable acidity for *Nelli* juice was measured as 2.25%, similar to the 2.34% reported by Kulkarani *et al*. (2017), however, higher than the 1.75% stated by Balakrishnan *et al*. (2021). Additionally, the titratable acidity of banana pseudostem juice (0.13%) was consistent with findings from the previous research study reported by Bornare and Sumaiya (2015). However, it deviated from the value of 0.0069% reported by Saravanan and Aradhya (2011). This finding suggests that banana pseudostem juice may exhibit a milder flavor profile, rendering it a suitable ingredient for formulating highly desirable healthy beverages.

In terms of sugar content, *Nelli* juice exhibited total and reducing sugar levels of 24.41% and 14.07%, respectively, aligning with the

findings of the research study by Parveen and Khatkar (2015). The banana pseudostem exhibited a significantly higher total sugar content of 48.36% ($p < 0.05$), with 3.03% reducing sugars. These findings differ from the values reported by Vazhacharickal *et al*. (2022) and highlights the variability of sugar content based on factors such as fruit maturity, processing methods, and varietal differences.

As presented in Table 2, the pH values for the T1 and T3 were measured at 3.22±0.08 and 3.99±0.31, respectively. This indicates that adding banana pseudostem juice raised the pH in the RTS formulation and highlighting the impact of ingredient selection on beverage properties. Consequently, the T1 beverage exhibited higher acidity (0.32±0.01%), which could affect flavor and consumer preference.

Further, the T1 and T3 beverages maintained constant ($p > 0.05$) TSS values of 10.00± 0.00%. However, significant differences ($p < 0.05$) were noted in total and reducing sugar content between the samples, indicating variations in sweetness and overall composition.

Proximate composition of raw materials and RTS beverages

The results of the proximate analysis of the raw materials are presented in Figure 1(A). The moisture content of *Nelli* was determined as 81.67±3.51%, which is consistent with the value of 81.2% reported by Pria and Islam (2019). However, the ash content of *Nelli* was measured as 1.43±0.02%, which differs from the 2.37% to 3.08% range reported by Minj *et al*. (2018) and Parveen and Khatkar (2015). This variation may be attributed to variations in maturity periods and the specific varieties of *Nelli* used.

The fat content of *Nelli* was found to be 0.65 ±0.08%, which contrasts with findings reported by a previous research study (Parveen and Khatkar, 2015), however, aligns with the results reported by Survase *et al*. (2018). The crude fiber content of *Nelli* was measured as 7.04±0.14%, and protein content was 2.94±0.10%, similar results reported by previous studies ranging from 7.18% to 22.35% and 2.05% to 3.17%, respectively (Parvez *et al*., 2020). In this study, the carbohydrate content of *Nelli* also aligns with findings reported by Parveen and Khatkar (2015). Further, the proximate composition values reported by Pushpakumara and Heenkenda (2007) for fat, carbohydrate, protein, and crude fiber in *Nelli* were 0.1%, 14.1%, 0.5%, and 3.4% in wet basis, respectively, which further highlights the consistency of these findings.

The proximate composition of banana pseudostem was characterized by protein, crude fiber and carbohydrate contents of 2.13 ±0.12%, 27.70±0.15% and 62.42±0.34%, respectively. These protein and crude fiber values align with studies conducted by Ma (2015), while the ash content of the present study was recorded as 1.61±0.03%, which differs from the value of 0.3% reported by the previous research study (Ma, 2015). Additionally, the moisture content of banana pseudostem was found to be 89.33±0.21%, and the fat content was 1.03±0.05%, which aligns with findings from previous studies (Ho *et al*., 2012; Ma, 2015).

The results of the proximate composition of the RTS beverages are illustrated in Figure 1 (B). A significant difference was observed between the T1 and T3 in terms of moisture, ash, fat, crude fiber and carbohydrate content ($p < 0.05$). Specifically, the moisture content of T1 was 86.82±0.55%, while T3 was measured as 87.35±0.83%, with an observed increase due to the addition of banana pseudostem juice.

The values of ash content for the T1 and T3 were 0.44±0.02% and 0.53±0.03%, respectively. The ash content in T3 was significantly higher than ($p < 0.05$) in T1, indicating that the incorporation of banana pseudostem juice increased the ash content of the beverage. Crude fiber content was notably affected by adding banana pseudostem, with values of 2.26±0.32% for T1 and 2.97±0.45% for T3. This increase can be attributed to the high crude fiber content of banana pseudostem, which highlights its potential as a

beneficial ingredient in beverage formulations Further, the presence of fat, protein, and carbohydrate content also showed significant differences ($p < 0.05$) between the samples. However, T3 exhibited lower amounts compared to T1. This reduction can be attributed to the high fiber content of the banana pseudostem, which may dilute the overall macronutrient composition (Pillai *et al*., 2024).

Antioxidant properties of raw materials

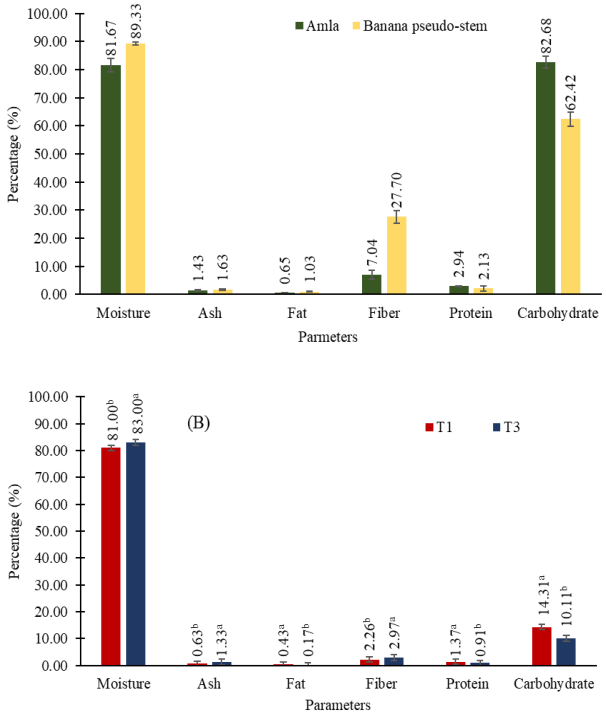

Figure 1: Proximate composition: (A) Raw materials; (B) RTS beverages

Bars with different letters (a-b) are significantly different ($p<0.05$); All the data except moisture is reported on dry wt. basis.

The antioxidant properties of raw materials and RTS beverages are summarized in Table 3. In this study, the total phenolic content, and flavonoid content of *Nelli* were 53.31±1.01 mg GAE/g of dry matter, 18.42±0.08 mg and CE/g of dry matter, respectively. The total phenolic content of *Nelli* was aligned with the previous research by Verma *et al*. (2018), where they found values ranging from 46.63 to 72.46 mg GAE/g. However, the total flavonoid content in this study differed from the findings by Halim *et al*. (2022). Additionally, total phenolic and flavonoid contents of banana pseudostems were recorded as 48.36±0.33 mg GAE/g of dry matter and 22.31±0.09 mg CE/g of dry matter, respectively. These values are consistent with the research studies reported by Saravanan and Aradhya (2011). The antioxidant capacities for *Nelli* and banana pseudostem were 68.12±0.06 and 71.32±0.05%, respectively. These differences indicate that variations in raw material composition can significantly influence the bioactive compound profile. Moreover, T3 exhibited greater flavonoid content and antioxidant capacity, whereas T1 contained a higher phenolic content. These findings suggest that the antioxidant potential is significantly influenced by the composition of the raw material (Saravanan and Aradhya, 2011).

Table 3: Antioxidant properties of raw materials and RTS beverages

Properties	Raw materials		RTS beverages	
	Nelli	Banana pseudostem	T1	T3
Phenolic content (mg GAE/g dry matter)	53.31 ± 1.01	48.36 ± 0.33	41.21 ± 0.53^{b}	38.32 ±0.81^{a}
Flavonoid content (mg CE/g dry matter)	18.42 ± 0.08	22.31 ± 0.09	11.02 ± 0.03^{a}	16.31 ±0.09^{b}
Antioxidant capacity (%)	68.12 ± 0.06	71.32 ± 0.05	58.35 ± 0.08^{a}	60.42 ±0.06^{b}

Mean±SD values of RTS beverages in each row with different superscripts (a – b) have significant differences at $p < 0.05$

Microbial count

The microbial counts of the RTS beverages are presented in Table 4.

Table 4: Total plate count and yeast and mold count of RTS beverages

Samples	Storage period	Total plate count (CFU/mL)	Yeast and mold count (CFU/mL)
T1	0 days	-	-
	30 days	3×10^2	-
	60 days	5×10^2	-
T3	0 days	-	-
	30 days	2×10^2	-
	60 days	4×10^2	-

Microbial testing is essential for determining the shelf life of food products, as microorganisms can lead to spoilage (Tarlak, 2023). The total plate count for the T1 sample was increased from 3×10^2 at 30 days to 5×10^2 CFU/ml at 60 days. In comparison, T3 recorded a lower initial count of 2×10^2 CFU/ml at 30 days, which rose to 4×10^2 CFU/ml by 60 days. These results indicate a steady increase in microbial load for both samples over the storage period, however, both remained well within the acceptable limit of 10^3 CFU/ml, as specified by the International Commission on Microbiological Specifications for Foods (Oranusi *et al*., 2013).

Notably, no yeast and mold counts were detected in all the samples for 2 month of storage period. This absence of yeast and mold indicates effective preservation methods were employed during the formulation and storage of both beverages. The lower initial microbial count in T3 suggests that incorporating banana pseudostem juice may contribute to its enhanced microbial stability, potentially due to its inherent antimicrobial properties (Sharma *et al*., 2017). The results validate that both T1 and T3 formulations are safe for consumption over the evaluated period.

Changes in physicochemical properties of RTS with storage period

The results of the physicochemical analysis of the RTS beverages, including Total Soluble Solids (TSS), acidity and pH, are presented in Table 5. T1 and T3 beverages exhibited an initial TSS of 10% at 0 days. By 30 days, TSS was increased to 12% for both samples, indicating that soluble solids remained stable during storage. This consistency suggests that the formulations retained their flavor and sweetness over time. Acidity levels for the control sample remained stable at 0.32% from 0 to 30 days and slightly decreased to 0.31% by 60 days. In contrast, T3 started with an acidity of 0.30% at 0 days, maintaining this level at 30 days before decreasing to 0.29% by 60 days. The slight decrease in acidity over time for both samples may indicate some changes in the formulation, but all values remained within acceptable limits for beverage stability (Bornare & Sumaiya, 2015).

Table 5: Physicochemical changes of RTS beverages with storage period

Samples	Storage period	TSS (%)	Acidity (%)	pH
T1	0 days	10 ±0.02	0.32 ±0.12	3.22 ±0.02
	30 days	12 ±0.02	0.32 ±0.05	3.31 ±0.01
	60 days	12 ±0.01	0.31 ±0.08	3.40 ±0.01
T3	0 days	10 ±0.03	0.30 ±0.06	3.99 ±0.01
	30 days	12 ±0.03	0.30 ±0.07	4.10 ±0.02
	60 days	12 ±0.02	0.29 ±0.04	4.40 ±0.02

The pH of the T1 sample increased from 3.22 at 0 days to 3.31 at 30 days and further to 3.40 at 60 days, suggesting a gradual increase in alkalinity. In the T3, the pH values started at a higher level of 3.99 at 0 days and increased to 4.1 and then to 4.4 over the storage period. The higher pH in T3 compared to the control indicates a more stable environment for microbial growth, although the absence of microbial counts suggests that both formulations were effectively preserved (Dissanayake, 2017). Therefore, the physicochemical analysis of both control (T1) and T3 samples indicates good stability during the storage period. The formulations retained their desirable characteristics, making them suitable for consumption.

CONCLUSIONS

This study concludes the potential of developing nutritious RTS beverages by utilizing banana pseudostem and *Nelli* juice. The formulation T3 (60% banana pseudostem and 40% *Nelli* juice) was the most preferred RTS beverage in sensory evaluations, indicating a favorable taste profile. The incorporation of banana pseudostem enriched the beverages with crude fiber, flavonoids, and antioxidant properties and ensured the products remained microbiologically stable over a two-month shelf life. Overall, these RTS beverages represent a sustainable solution that leverages agricultural by-products while providing health benefits, highlighting their potential as viable options in the functional beverage market.

AUTHOR CONTRIBUTION

AAJ conducted the study and prepared the initial draft. VP contributed to the original writing and performed editing. SV conceptualized the study, provided review and editing, and oversaw project administration.

ACKNOWLEDGEMENT

The authors would like to acknowledge Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna, Sri Lanka for providing the necessary facilities to conduct this research study.

REFERENCES

Balakrishnan, S., Wickramasinghe, G.L.D., and Wijayapala, U.G.S. (2021) 'Investigation on mechanical and chemical properties of mechanically extracted banana fibre in pseudostem layers: From Sri Lankan banana (Musa) cultivation waste', *Journal of Engineered Fibers and Fabrics*, 16, p 1-10. https://doi.org/10.1177/15589250211059832 [Accessed: 11 April 2024]

Bornare, D.T., and Sumaiya, K. (2015) 'Physicochemical and Sensory Evaluation of [RTS] Beverage by Incorporating banana Pseudostem Juice in Papaya', *International Journal of Engineering Research*, 4, p 403-406, https://doi.org/10.17577/ijertv4is080393 [Accessed: 6 November 2023]

Dasaroju, S., and Gottumukkala, K. M. (2014) 'Current trends in the research of *Emblica officinalis* (Amla): A Pharmacological Perspective', *International Journal of Pharmaceutical Sciences Review and Research*, 24, p 150-59 [Accessed: 7 July 2023].

Deng, G., Sheng, O., Bi, F., Li, C., Dou, T., Dong, T., Yang, Q., Gao, H., Liu, J., Zhong, X., Peng, M., Yi, G., He, W. and Hu, C. (2020) 'Metabolic profiling in banana pseudo-stem reveals a diverse set of bioactive compounds with potential nutritional and industrial applications', *Phyton-International Journal of Experimental Botany*, 89, p 1102–1130. https://doi.org/10.32604/phyton.2020.010970 [Accessed: 4 June 2023]

Dissanayake, D., M., L., N., K., (2017) 'Effect of increasing acidity on shelf-life of bottled mixed fruit juice drink', *International Journal of Life Sciences Research*, 5: p 121-127, Retrieved from www.researchpublish.com [Accessed: 4 April 2023]

Godswill, A., C. (2019) 'Proximate composition and functional properties of different grain flour composites for industrial applications'. *International Journal of Food Sciences*, 2: p 43-64. https://doi.org/10.47604/ijf.1010 [Accessed: 1 May 2024]

Goraya, R., K., and Bajwa, U. (2015) 'Enhancing the functional properties and nutritional quality of ice cream with processed amla (*Indian gooseberry*)'. *Journal of Food Science and Technology*, 52: p 7861–7871. https://doi.org/10.1007/s13197-015-1877-1 [Accessed: viewed 2 May 2024]

Halim, B., Syahputra, R., A., Adenin, I., Lubis, H., P., Mendrofa, F., Lie, S., and Nugraha, S., E. (2022) D'etermination of phytochemical constituent, antioxidant activity, total phenol and total flavonoid of extract

ethanol *Phyllanthus emblica* fruit', *Pharmacognosy Journal*, 14: p 63–67. https://doi.org/10.5530/pj.2022.14.9 [Accessed: 9 March 2024]

Ho, L.H., Aziah, N. and Bhat, R. (2012) 'Mineral composition and pasting properties of banana pseudo-stem flour from *Musa acuminata* × *balbisiana*', *International Food Research Journal*, 19, p 1479–1485. Available at: https:// www.researchgate.net/ publication/264235609 (Accessed: 1 June 2023).

Ikram, A., Khalid, W., Aziz, M., Arif, M.A., Jha, R.P., Khalid, M.Z. and Sultana, F. (2021) 'Nutritional and biochemical composition of amla (*Emblica officinalis*) and its therapeutic impact: A review', *Acta Scientifica Nutritional Health*, 5, pp. 153–160. doi:10.31080/ asnh.2020.05.0821.

Kulkarni, P., Pandey, H., Sharma, A.K. and Joshi, D.C. (2017) 'Physico-chemical properties of Aonla fruit and juice', *Chemical Science Review and Letters*, 6, p 1343–1347. (Accessed: 5 September 2023)

Kumar, S., Chitra, C., Kohli, D., Mishra, R., and Upadhyay, S. (2017) 'Effects of refrigeration storage on the ascorbic acid (VIT C) content of pear-amla based ready-to-serve (RTS) beverages', *International Journal of Engineering Research and Applications*, 7, p 24–29. doi:10.9790/9622-0707032429. (Accessed: 30 April 2023)

Mailoa, M., N., Tapotubun, A., M. and Matrutty, T., E., A., A. (2017) 'Analysis of total plate count (TPC) on fresh steak tuna applications edible coating *Caulerpa* sp. during storage at chilling temperature', *IOP Conference Series: Earth and Environmental Science*, 89. doi:10.1088/1755-1315/89/1/012014 (Accessed: 19 August 2023,

Ma, J. (2015) 'Banana Pseudostem : properties nutritional composition and use as food'. Thesis, University of New South Wales, Australia, (Accessed: 7 January 2024)

Meena, V.S., Sharma, P.C., Yadav, V.S., Meena, R.S. and Bhushan, B. (2017) 'Development and storage studies of Aonla (*Emblica officinalis* Gaertn.) based ready-to-serve (RTS) using different sweeteners', *International Journal of Bio -resource and Stress Management*, 8, p 790– 795. doi:10.23910/ IJBSM/2017.8.6.3C0078 (Accessed: 28 March 2024)

Minj, P., Mahilang, K., K., S., Sonboier, K., K., Porte, P. and Lal, K. (2018) 'Some physico-chemical properties of dried amla', *International Journal of Pure & Applied Bioscience*, 6, pp. 642–644. doi:10.18782/2320-7051.6178 (Accessed:1 March 2024)

Mydhili, M., Pugalendhi, L., Indu Rani, C., Auxcilia, J. and Uma, D. (2022) 'Proximate composition of different varieties of banana pseudostem powder for nutritional and biochemical properties', *Biological Forum – An International Journal*, 14, p 331–334 (Accessed: viewed 2 May 2024

Naseeha, N.F., Pushparaja, V. and Vasantharuba, S. (2023) 'Development of composite biscuits incorporated with pineapple peel powder and evaluation of their quality characters', *Tropical Agricultural Research and Extension*, 26, pp. 151–161. doi:10.4038/ tare.v26i3.5643 (Accessed: 4 April 2024)

Nilugin, S. and Mahendran, T. (2011) 'Preparation of ready-to-serve (RTS) beverage from palmyrah (*Borassus flabellifer* L.) fruit pulp', *Journal of Agricultural Sciences*, 5, p 80–88. doi:10.4038/jas.v5i2.2787 (Accessed: 24 June 2024)

Oranusi, S.U., Oguoma, O.I. and Agusi, E. (2013) 'Microbiological quality assessment of foods sold in student cafeterias', *Global Research Journal of Microbiology*, 3, p 1–6 (Accessed: 1 June 2023

Parveen, K. & Khatkar, B.S. (2015) 'Physico-chemical properties and nutritional composition of aonla (*Emblica officinalis*) varieties', *International Food Research Journal*, vol. 22, p 2358-2363,

(Accessed: 2 May 2024)

Parvez, M.S., Jashin, N., Yesmin, M.T., Reza, M.S.A. & Akter, N. (2020) 'Proximate, phytochemical and antioxidant activity of amla powder and amla candy', *Journal of Environmental Science & Natural Resources*, vol. 13, p 82-86. https://www.banglajol.info/index.php/JESNR/article/view/60693/41675. (Accessed: viewed 9 May 2024)

Phuyal, N., Jha, P.K., Raturi, P.P. & Rajbhandary, S. (2020) 'In vitro antibacterial activities of methanolic extracts of fruits, seeds, and bark of *Zanthoxylum armatum* DC.', *Journal of Tropical Medicine*. https://doi.org/10.1155/2020/2803063 (Accessed: viewed 6 June 2024)

Pillai, G.S., Morya, S., Khalid, W., Khalid, M.Z., Almalki, R.S. & Siddeeg, A. (2024) 'Banana pseudostem: An undiscovered fiber enriched sustainable functional food', *Journal of Natural Fibers*, vol. 21, no. 1, p 1-17, Taylor & Francis Ltd. https://doi.org/10.1080/15440478.2024.2304004 (Accessed: viewed 11 July 2024)

Pria, F., & Islam, M., S., (2019) '*Phyllanthus emblica* Linn. (Amla) - A natural gift to humans: An overview', *Journal of Diseases and Medicinal Plants*, vol. 5, p 1-9 https://doi.org/10.11648/j.jdmp.20190501.11 (Accessed: viewed 7 August 2023)

Pushpakumara, D., K., N., G. & Heenkenda, H.M.S. (2007) '*Underutilized fruit trees in Sri Lanka*', vol. 1, p 180-221 (Accessed: 9 February 2024)

Ravi, U., Menon, L. & Gomathy, G. (2011) 'Development and quality assessment of value-added plantain stem juice incorporated with grape juice', *Indian Journal of Natural Products and Resources*, vol. 2, p 204-210, (Accessed: 7 November 2023)

Rittisak, S., Lonuch, N., Buakeeree, S. & Yimtoe, S. (2023), 'Development of jelly drink from cultivated banana pseudostem juice (*Musa sapientum* L.) and pineapple juice supplemented with pineapple pulp', *Food Research*, vol. 7, p 52-59, viewed 4 May 2024, https://doi.org/10.26656/fr.2017.7(2).721 (Accessed on: 4 May 2024).

Saeed, I., Shaheen, S., Hussain, K., Khan, M.A., Jaffer, M., Mahmood, T. & Khan, F. (2019), 'Assessment of mold and yeast in some bakery products of Lahore, Pakistan based on LM and SEM', *Microscopy Research and Technique*, vol. 82, pp. 85-91, viewed 14 May 2024, https://doi.org/10.1002/jemt.23103 (Accessed on: 14 May 2024).

Saqib, A. A. N. & Whitney, P.J. (2011), 'Differential behaviour of the dinitrosalicylic acid (DNS) reagent towards mono- and disaccharide sugars', *Biomass and Bioenergy*, vol. 35, p 4748-4750, viewed 25 May 2024, https://doi.org/10.1016/j.biombioe.2011.09.013 (Accessed on: 25 May 2024).

Saravanan, K. & Aradhya, S.M. (2011), 'Potential nutraceutical food beverage with antioxidant properties from banana plant bio-waste (pseudostem and rhizome)', *Food & Function*, vol. 2, p 603-610, viewed 23 July 2023, https://doi.org/10.1039/c1fo10071h (Accessed on: 23 July 2023).

Sewwandi, S.D.C., Arampath, P.C., Silva, A.B.G. & Jayatissa, R. (2020), 'Determination and comparative study of sugars and synthetic colorants in commercial branded fruit juice products', *Journal of Food Quality*, 2020, viewed 16 March 2024, https://doi.org/10.1155/2020/7406506 (Accessed on: 16 March 2024).

Sharma, M., Patel, S.N., Sangwan, R.S. & Singh, S.P. (2017), 'Biotransformation of banana pseudostem extract into a functional juice containing value-added biomolecules of potential health benefits', *Indian Journal of Experimental Biology*, vol. 55, p 453-462, viewed 21 December 2023, https://www.researchgate.net/publication/318284589 (Accessed on: 21 December 2023).

Shiva, K.N., Adiyaman, P., Naik, R. & Marimuthu, N. (2018), 'Development and standardisation of banana pseudostem-based novel functional blended ready to drink (RTD) beverages

and studies nutritional changes during storage', *LS: International Journal of Life Sciences*, vol. 7, p. 151, viewed 9 December 2023, https://doi.org/10.5958/2319-1198.2018.00021.0 (Accessed on: 9 December 2023).

Srivasuki, K.P. (2012), 'Nutritional and health care benefits of amla', *Journal of Pharmacognosy*, vol. 3, pp. 147–151, viewed 1 March 2024 (Accessed on: 1 March 2024).

Survase, A.G., Babar, K.P. & Bornare, D.T. (2018), 'Effect of Indian gooseberry juice on physico-chemical and sensory quality characteristics of soybean-based yoghurt', *International Journal of Chemical Studies*, vol. 6, pp. 3296–3300, viewed 21 November 2023 (Accessed on: 21 November 2023).

Surya, N., Poornakala, S.J., Kanchana, S. & Hemalatha, G. (2020), 'Development of amla (*Emblica officinalis*) ready to serve beverage fortified with dietary fiber', *Emergent Life Sciences Research*, vol. 6, pp. 6–15, viewed 18 May 2024, https://doi.org/10.31783/elsr.2020.610615 (Accessed on: 18 May 2024).

Swarnalakshmi, C.S., Manisha, C.P., Harini, B., Akshara, J., Joshika, G. & Keerthana, R. (2019), 'Optimization and standardization of lemongrass incorporated into pseudostem and mint extracts-based isotonic drink', *International Journal of Advance Research, Ideas and Innovations in Technology*, vol. 5, pp. 1089–1093, viewed 2 June 2023, https://www.academia.edu/download/59980481/V5I3-162220190711-94310-12ubpoy.pdf (Accessed on: 2 June 2023).

Tarlak, F. (2023), 'The use of predictive microbiology for the prediction of the shelf life of food products', *Foods*, vol. 12, p. 4461, viewed 2 April 2024, https://doi.org/10.3390/foods12244461 (Accessed on: 2 April 2024).

Vazhacharickal, P.J., Mathew, J.J., Thomas, T., Sreejith, P. & Sabu, M. (2022), 'Comparative study using banana peel and male flower as substrates for amylase production using *Aspergillus Niger* in Kerala', vol. 7, pp. 124-150, viewed 5 May 2024, https://www.ijprajournal.com/10.35629/7781-070313541378 (Accessed on: 5 May 2024).

Verma, M., Rai, G.K. & Kaur, D. (2018), 'Effect of extraction solvents on phenolic content and antioxidant activities of Indian gooseberry and guava', *International Food Research Journal*, vol. 25, pp. 762-768, viewed 12 December 2023, http://www.ifrj.upm.edu.my (Accessed on: 12 December 2023).

Vilas-Boas, A.A., Magalhães, D.D., Campos, D.A., Porretta, S., Dellapina, G., Poli, G. & Pintado, M. (2022), 'Innovative processing technologies to develop a new segment of functional citrus-based beverages: Current and future trends', *Foods*, viewed 2 January 2024, https://doi.org/10.3390/foods11233859 (Accessed on: 2 January 2024).