

SENSORY EVALUATION AND CONSUMER ACCEPTABILITY OF AN AMLA-BASED ANTIOXIDANT HERBAL BEVERAGE

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Abstract

Background: In today's fast-paced world, commercial food and beverages have become staples in daily life. However, many of these products contain harmful pesticides and synthetic additives that pose serious health risks. Functional beverages can deliver nutrients, yet few products blend antioxidant-rich herbs with a probiotic base. **Objective:** This study aimed to develop a refreshing, nutrient-dense beverage using *Phyllanthus emblica* (amla), *Murraya koenigii*, *Mentha spicata*, *Coriandrum sativum*, *Zingiber officinale*, and fermented rice water and to compare it with a similar formulation without amla. To evaluate both consumer acceptability and the nutritional attributes of the beverages. **Methods:** Two formulations (with/without amla) were prepared and their sensorial attributes like aroma, taste, appearance, texture, and overall acceptability were assessed by 31 healthy volunteers using a nine-point hedonic rating scale laboratory analysis was carried out to quantify nutrients following standard procedures. **Results:** The amla beverage showed higher overall acceptability (7.90 ± 0.75) than control (7.40 ± 0.78 ; $p = 0.046$) and higher flavor/taste scores ($p = 0.027$). Results are presented with 95% confidence intervals to indicate precision. **Conclusion:** Combining amla with a mint–coriander–curry leaf–ginger blend on a fermented rice-water base yields a palatable, nutrient-dense beverage. This work adds to previous studies on amla based drinks by demonstrating consumers' preference to the balanced sourness of amla and the complementary herbal notes, which together enhanced the flavor complexity and overall acceptability of the beverage.

Keywords: Functional Foods; Hedonic Scale; *Phyllanthus emblica*; Refreshing Drink; Sensory Evaluation

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Introduction

Functional food beverages, which offer health benefits beyond basic nutrition, are increasingly attracting consumer interest due to their potential in preventing chronic diseases and promoting wellness (Usharani *et al.*, 2019). These drinks containing bioactive compounds from fruits, vegetables, herbs, and probiotics have emerged as potential products that can enhance immunity, promote digestion, and support detoxification (Prakash *et al.*, 2023). Increasing consumer awareness and demand for nutrient-dense, sensory-satisfying products have further inspired research into functional beverages using fermentation and incorporating traditional herbs techniques (Ballester *et al.*, 2022).

Amla (*Phyllanthus emblica*), commonly referred as Indian Gooseberry, is a rich source of vitamin C (ascorbic acid) and contains bioactive components such as apigenin, ellagic acid, gallic acid, quercetin, luteolin, corilagin, and other polyphenols that contribute to its potent antioxidant capacity (Medabalimi *et al.*, 2024). Its antidiabetic, anti-inflammatory, gastrointestinal protective, anticancer, and neuroprotective properties make amla highly valued in traditional medicine. Amla is also known for its astringent, laxative, diuretic, refrigerant properties and is a key ingredient in various traditional formulations (Ganesan *et al.*, 2013).

Similarly, mint (*Mentha spicata*) and ginger (*Zingiber officinale*) provide well-documented anti-inflammatory and digestive benefits. Mint contains bioactive compounds such as hesperidin, luteolin-7-O-rutinoside, eugenol, rosmarinic acid, eriocitrin, caffeic acid, and ferulic acid, which exhibit antioxidant, lipid-lowering, and anti-inflammatory effects (Brown *et al.*, 2019). Ginger, rich in bioactives such as gingerol and shogaol, demonstrates broad-spectrum of antimicrobial, anti-inflammatory, and anticancer properties (Vishakha Dunkwal, 2021).

Leafy herbs such as curry leaves (*Murraya koenigii*) and coriander leaves (*Coriandrum sativum*) boost the nutritional profile of the beverages. Curry leaves contain antioxidant, anti-inflammatory, and antidiabetic properties, while coriander leaves provide phenolic compounds like 4-hydroxycoumarin, tartaric acid, diosmin, luteolin, gallic acid, esculin, apigenin, and vicenin, which impart notable antidiabetic, antidepressant and antioxidant effects (Srilakshmi, 2018; Mamoon *et al.*, 2023).

While the therapeutic properties and nutrients of these ingredients have been investigated individually, few studies have explored their

combined use in beverages that integrate probiotics with antioxidant-rich herbs and fruits (Stephen *et al.*, 2023). One study demonstrated that incorporating amla into a fruit-based drink significantly enhanced its antioxidant potential and sensory acceptability, making it a promising ingredient for the formulation of functional beverages (Bhalerao *et al.*, 2020). Despite evidence that amla-based drinks improve mineral bioavailability and antioxidant status (Anshuman, 2023), few studies have examined their integration with other botanicals. Fermented rice water offers a natural, probiotic-rich substrate that supports nutrient absorption and gut microbiome balance. Traditional fermentation processes promote the proliferation of beneficial bacteria and improve the bioavailability of micronutrients. Recent studies report that fermented rice water may help modulate inflammation and gut dysbiosis, making it a promising base for functional beverages (Anbalagan *et al.*, 2024). There remains a research gap in assessing the sensory acceptability of an amla-herb-fermented rice water beverage.

This led to the study's objectives of formulating a novel beverage using amla, curry leaves, coriander leaves, mint, ginger, and fermented rice water, and to assess its sensory qualities, nutritional profile, and potential health benefits. The findings aim to establish a palatable, health-promoting drink that provides an inexpensive alternative to commercial beverages and can support gut health and immunity.

Unlike previous amla beverages that used fruit juices or sugar syrups as the matrix, our formulation integrates a fermented rice-water base with a multi-herb blend (mint, coriander, curry leaves, and ginger) and amla. This combination has not, to our knowledge, been evaluated for consumer acceptability in a within-subject design, and it provides new insight that a balanced sourness-aroma profile on a probiotic base can enhance liking compared with a similar formulation without amla.

Materials and Methods

Materials

Parboiled ration rice was procured from the local public distribution system. Fresh herbs, including amla (*Phyllanthus emblica*), ginger (*Zingiber officinale*), mint leaves (*Mentha spicata*), coriander leaves, and curry leaves were purchased from a local vegetable market in Chennai, India. All ingredients were thoroughly washed under

running water to remove contaminants and dust before further processing.

Preparation of Fermented Rice Water

One kilogram of rice was cleaned with potable water to remove impurities and cooked in excess water using the conventional boiling method. After cooking, the starch water was drained. Approximately 1,000 ml of clean drinking water was added to the cooked rice and transferred into a clean, covered container and allowed to ferment naturally under ambient conditions for 24 h to promote the proliferation of beneficial microflora. The fermented rice water was subsequently filtered through a fine muslin cloth before blending with the herbal paste.

Processing of Herbal Ingredients and Beverage Formulation

Amla fruits were deseeded, and then chopped into fine pieces. After being cleaned separately, the herbs were weighed as follows: Formulation details (per 100 ml): amla 5.0 g; ginger 0.5 g; mint

leaves 0.5 g; coriander leaves 0.5 g; curry leaves 0.5 g; fermented rice water 100 ml; and salt standardized at 0.10 g/100 ml. These concentrations were derived from the batch recipe (50 g amla and 5 g of each herb per 1 L fermented rice water) to ensure reproducibility. The control drink excluded amla but maintained all other components and the same salt level. The measured ingredients were ground into a fine paste for around five minutes using a domestic mixer grinder.

Beverage Preparation

The freshly prepared herbal paste was thoroughly mixed with the filtered fermented rice water, and salt was added to taste. The beverage was stored under refrigeration at 4°C until further use. Although 24-hour natural fermentation promotes beneficial microbial activity, there is also potential for spoilage organisms. However, the low pH (≤ 4.2) and immediate refrigerated use minimize this risk.

Figure 1 displays two green beverages used in a comparative analysis study. Sample 1 (left) represents the formulated Amla-based beverage, known for its rich antioxidant and vitamin C content. Sample 2 (right) is the control beverage



Sample 1 Amla Beverage



Sample 2 Controlled Beverage

Figure 1. Visual comparison of Amla-Based Functional Beverage (Sample 1) and Standard Control Beverage (Sample 2) in Identical Glass Containers

Table 1. Nutrient composition of the beverages sample 1 and sample 2 as per the NIN

Nutrient	With Amla	Without Amla
Vitamin C (mg/100 ml)*	143.6	2.62
Calcium (mg/100 ml)*	80	70
Iron (mg/100 ml)*	1.80	1.14
β -carotene (μ g/100 ml)*	5,181	5,179
Thiamine B1 (mg/100 ml)*	0.16	0.15
Riboflavin B2 (mg/100 ml)*	0.04	0.03
Niacin B3 (mg/100 ml)*	0.20	0.14
Pantothenic Acid B5 (mg/100 ml)*	0.27	0.09
Pyridoxine B6 (mg/100 ml)*	0.20	0.06
Biotin B7 (μ g/100 ml)*	1.17	0.50
Folic Acid B9 (μ g/100 ml)*	12.38	8.45

*Values calculated from NIN (2017) food composition database per 100 ml of beverage (based on formulation: 5.0 g amla + 0.5 g each herb per 100 ml fermented rice water). Values represent calculated estimates from raw ingredient composition.

Table 2. Nutrient composition of the beverages sample 1 & sample 2 expressed as mean $\pm$ SD

Nutrient	With Amla (mean $\pm$ SD)	Without Amla (mean $\pm$ SD)
Vitamin C (mg/100 ml)*	143.6 $\pm$ 3.2	2.62 $\pm$ 0.05
Calcium (mg/100 ml)*	80.0 $\pm$ 1.6	70.0 $\pm$ 1.4
Iron (mg/100 ml)*	1.80 $\pm$ 0.04	1.14 $\pm$ 0.03
β -carotene (μ g/100 ml)*	5181 $\pm$ 104	5179 $\pm$ 103
Thiamine B1 (mg/100 ml)*	0.16 $\pm$ 0.003	0.15 $\pm$ 0.003
Riboflavin B2 (mg/100 ml)*	0.04 $\pm$ 0.001	0.03 $\pm$ 0.001
Niacin B3 (mg/100 ml)*	0.20 $\pm$ 0.004	0.14 $\pm$ 0.003
Pantothenic Acid B5 (mg/100 ml)*	0.27 $\pm$ 0.005	0.09 $\pm$ 0.002
Pyridoxine B6 (mg/100 ml)*	0.20 $\pm$ 0.004	0.06 $\pm$ 0.001
Biotin B7 (μ g/100 ml)*	1.17 $\pm$ 0.02	0.50 $\pm$ 0.01
Folic Acid B9 (μ g/100 ml)*	12.38 $\pm$ 0.25	8.45 $\pm$ 0.17

*Calculated values per 100 ml of beverage derived from the NIN (2017) food composition database. SD values represent the variability across triplicate preparations. Measured laboratory values for the final processed beverage are reported separately in the Laboratory Analysis section.

without Amla, used to evaluate the functional and sensory impact of Amla addition.

Nutritional Analysis

Nutrient composition of the ingredient was calculated by Indian food composition table NIN (2017) (Longvah *et al.*, 2017) (Table 1).

Nutritive value =

$$\frac{\text{Amount of the ingredient utilized} \times \text{Nutrient content per 100gm}}{100}$$

Amla to a large extent promotes vitamin C content (143.6 mg vs 2.62 mg), aligning with previous findings that amla is one of the richest natural sources of vitamin C with strong antioxidant potential (Gómez de Cedrón *et al.*, 2020; Avinash *et al.*, 2024). Calcium and β -carotene remained unchanged in both versions due to the presence of mint and curry leaves (Salve, 2020). The inclusion of amla also increased iron levels (1.80 mg vs 1.14 mg), supporting earlier studies on its role in improving mineral content in functional beverages (Talreja *et al.*, 2021). Furthermore, the levels of B-complex vitamins such as pyridoxine (0.20 mg vs 0.06 mg), pantothenic acid (0.27 mg vs. 0.09 mg), and folic acid (12.38 μ g vs. 8.45 μ g) increased with the inclusion of amla, consistent with its known micronutrient composition (Tewari *et al.*, 2023). This intensification confirms that incorporating amla not only boosts the beverage's antioxidant and immune-supporting properties but also remarkably improves its micronutrient profile, making it a potent functional health beverage (Devi *et al.*, 2020). The formulation of the ready to serve drink involved a mixture of amla, mint, coriander leaves, curry leaves, and ginger. The ingredients were selected based on their nutritive value, particularly high vitamin C, calcium, and antioxidant potential

as reported in the Nutritive Value of Indian Foods (Dar *et al.*, 2022). Similar RTS beverage formulations have used amla and Kinnow blends with pasteurization and storage (Purewal *et al.*, 2022) or optimized fruit-vegetable combinations using Response Surface Methodology. All chemical analyses were performed in triplicate, and results were expressed as mean $\pm$ SD.

Analysis revealed that the amla-containing beverage was markedly richer in micronutrients compared with the control drink (Table 2). The amla beverage contained 143.6 mg vitamin C per serving versus 2.62 mg in the control. Similarly, iron and calcium contents were 1.80 mg and 80 mg, respectively, in the amla beverage, compared with 1.14 mg and 70 mg, in the control. Pantothenic acid and folic acid also showed notable increases -0.27 mg and 12.38 μ g in the amla beverage versus 0.09 mg and 8.45 μ g in the control. Total polyphenols were substantially higher in the amla beverage, suggesting strong antioxidant potential.

Laboratory Analysis

The antioxidant beverage was submitted to MATS India Pvt. Ltd. (Laboratory Services Division, Chennai) for vitamin, mineral, and microbiological analysis. The laboratory centre is accredited by NABL (National Accreditation Board for Testing and Calibration Laboratories; ISO/IEC 17025:2005) and certified under ISO 9001, ISO 14001, and ISO 18001 standards. It is also recognized by FSSAI, APEDA, and MoEF, Government of India. Representative samples were analysed for their nutritional composition - including vitamin C, iron, calcium, and B-complex vitamins - using standard AOAC procedures. Total polyphenol content was estimated spectrophotometrically, and microbiological safety was assessed using standard plate count techniques.

Nutritional parameters, including moisture (96.38 g/100g), protein (0.23 g/100g), carbohydrate (1.04 g/100g), and energy (5.36 kcal/100g) were assessed. Moisture content was determined by the AOAC 925.10 oven drying method at 105°C until constant weight, using a laboratory hot air oven (LabTech, LDO 060E). Mineral analysis showed calcium (3.29 mg/ 100ml) and iron (0.12 mg/100 ml). Vitamin C content was 18.01 mg/100 ml, authenticating the antioxidant properties of the drink. Microbiological tests confirmed the absence of pathogenic bacteria including *Salmonella spp.*, *Vibrio cholerae*, *Listeria monocytogenes*, and *Escherichia coli* confirming the microbiological safety of the formulation. Calcium and iron also showed reduced levels, likely due to dilution and removal of insoluble components during filtration, a trend noted in similar fiber-enriched or fermented amla drinks (Sharma *et al.*, 2022). In this study, nutrient profiling included protein, carbohydrate, vitamin C, iron, and calcium using standard protocols, comparable to earlier approaches in low-calorie herbal RTS development (Das *et al.*, 2021). The vitamin C content of the final beverage (18.01 mg/100 ml) showed a ~12.5% retention from the total calculated value of 143.6 mg/100 g based on raw ingredients. This aligns with studies reporting moderate retention of ascorbic acid post-processing in amla-based beverages (Patel *et al.*, 2016). Vitamin C retention (%) was calculated as: (vitamin C after processing / vitamin C before processing) × 100 Although β-carotene potential presence is due to high mint and curry leaf content (combined value >5,000 µg/100 g) suggests the scope for further antioxidant profiling. Differences between calculated and laboratory-tested values may be attributed to processing losses, moisture variation, and analytical precision limitations.

The calculated values are typically derived from food composition databases that report nutrient content in raw, unprocessed ingredients under ideal conditions. In contrast, laboratory values reflect the actual nutrient content after processing, handling, and storage, where losses are inevitable. Heat, oxidation, enzymatic activity, and pH changes during preparation can degrade sensitive nutrients such as vitamin C and certain B vitamins. Furthermore, variations in the nutrient composition of the raw materials, influenced by factors such as variety, maturity, and growing conditions, may result in lower measured values than the reference data. Therefore, the higher calculated values compared with laboratory results are expected and align with known effects of processing on nutrient retention.

All analyses were conducted in triplicate for reliability of results.

Organoleptic Evaluation

The most commonly employed method in sensory assessment is the Hedonic scale, which assesses the degree of consumer liking for food products. In practice, 9-point, 7-point, and 5-point Hedonic scales are frequently applied. The 9-point scale typically ranges from “like extremely” to “dislike extremely”. It is generally recommended that a scale should include at least five points to provide meaningful results (Mihafu *et al.*, 2020). Testing by sensory attributes like appearance, colour, flavour, taste, texture, and overall acceptability using nine Hedonic rating scale with 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely. Thirty-one volunteers have tasted and scored accordingly. Consumer acceptability was not assessed across different age or cultural groups; further research should explore these variations. Exploring food-based experiences, like sensory evaluation, will be valuable as they are shared across different populations and cultures. However, past research has proved that cognitive styles vary both within and between cultures (Beekman and Seo, 2023). This procedure helps Food industry to understand variations in consumer’s feedback and behaviour towards their target audience, resulting in higher customer satisfaction (Marimuthu, 2019).

Ethical Approval

This study protocol was approved by the Meenakshi Academy of Higher Education & Research Ethical Board in accordance with the relevant guidelines and regulations. (DHR Registration No: EC/NEW/INST/2023/3553) (CDSCO Registration No: ECR/1906/Inst/TN/2023) Reference number: MAHER/IEC/ PhD/124/APRIL25.

Selection and Training of Panellists

Sensory evaluation was carried out with 31 volunteers. Participants were adults who voluntarily agreed to participate after receiving and signing an Informed Consent Form and Participant Information Sheet, which clearly outlined the purpose of the study, ingredients used, procedures involved, potential risks (none anticipated), and their right to withdraw at any point without consequence. No invasive procedures or identifiable data collection occurred, and the study posed no risk

to participants. All formal ethical principles were strictly followed.

A preliminary sensory screening was conducted to assess participants' ability to recognize minute variations in organoleptic properties. From 35 volunteers aged between 20 and 40 years, 31 were selected in accordance with the ability to identify and perceive basic tastes in minimal thresholds. The sensory panel size (n=31) falls within the range recommended for trained/consumer sensory studies in similar beverages. This age group was intentionally chosen, as it represents a consumer segment typically associated with greater health consciousness. All selected individuals were non-smokers and non-alcoholic (Table 3).

Panellist Training Protocol

The selected panelists underwent structured training in sensory evaluation techniques. They were educated on various sensory analysis methods and informed about potential sources of bias, such as halo effects, stimulus errors, and psychological influences like habituation. Emphasis was placed on objectivity and accuracy during evaluation. Only healthy individuals with no illnesses (e.g., cold or fever) affecting taste or smell were allowed to participate (Torrico *et al.*, 2023). Panelists were guided in the use of sensory scorecards, with detailed explanations on score ranges, the meaning of numerical values, and accurate documentation of sensory impressions. Similar training and hedonic

scoring approaches have been effectively used in prior sensory studies to enhance reliability and consumer-focused analysis (Sugumar and Guha., 2022).

Panel description and eligibility: Thirty-one adults (20-40 y; 15 males, 16 females), healthy, non-smokers, with no known allergies to the ingredients, provided informed consent (Ethics Ref: MAHER/IEC/PhD/124/APRIL25). Participants received a short orientation in using the 9-point Hedonic scale; testing followed key principles of ISO 8586 (minimizing bias via controlled lighting and temperature, randomized serving order, and palate cleansing).

A sensory evaluation was conducted in a controlled environment at 25±1°C under constant cool-white fluorescent lighting to minimize external variability. To ensure consistency and minimize bias, samples were served in a randomized order using identical cups and spoons. Drinking water was provided to rinse the mouth after tasting each sample, in order to cleanse the palate and avoid residual flavour interference. These measures supported the accuracy and reliability of the sensory data collected.

Statistical Analysis

SPSS software (Version 22.0) was used to perform one-way analysis of variance (ANOVA) for sensory and nutritional data. Differences at $p < 0.05$ were considered statistically significant. Because each participant rated both formulations, data were

Table 3. Summarizing the gender, age group, education level, and dietary habits of panelists

Characteristic	Category	Number of Panelists (n)	Percentage (%)
Age Group (years)	20-30	18	58.1
	31-40	13	41.9
Gender	Male	15	48.4
	Female	16	51.6
Education Level	Primary	9	29.0
	Graduate	22	71.0
Dietary Habit	Mixed diet	31	100.0

Table 4. Mean (±SD) sensory scores of the Amla and control beverage

Attribute	Amla drink (Mean±SD)	Control drink (Mean±SD)	p-value
Appearance	7.93±0.85	7.46±0.81	0.054
Aroma	8.07±0.73	7.62±0.69	0.041
Flavor/Taste	8.32±0.70	7.80±0.64	0.027
Texture	7.88±0.67	7.40±0.63	0.063
Overall acceptability	7.90±0.75	7.40±0.78	0.046

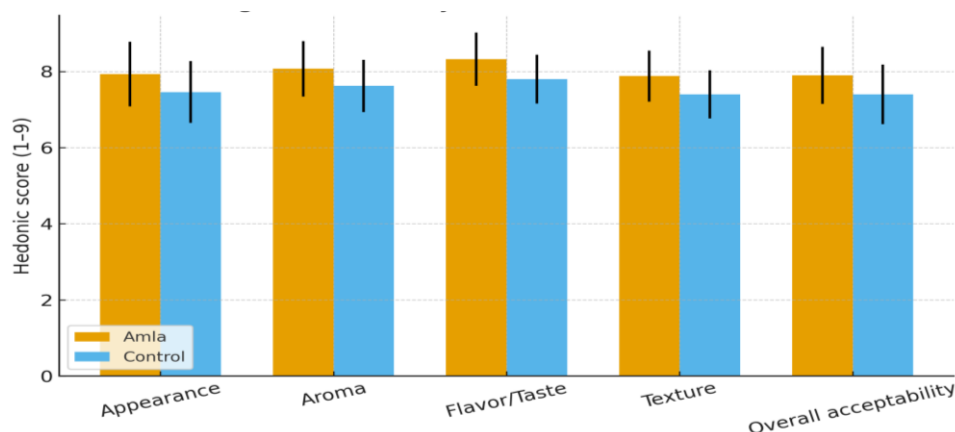


Figure 2. Sensory evaluation (mean±SD)

analyzed using a within-subjects (repeated-measures) model with one factor (formulation). We report p-values at $\alpha = 0.05$, two-tailed. Since only two levels were compared, no post-hoc test was required. To aid interpretation, we also report 95% confidence intervals for group means and Cohen's d effect sizes (pooled SD approximation) (Table 4 and Figure 2).

Results and Discussion

Our results extend recent findings on amla beverages by showing that a fermented base plus herbal aromatics tilts preference toward the amla formulation, consistent with reports that consumers favor balanced-sour functional drinks. We discuss these trends in light of recent functional beverage literature and highlight the practical implication that pairing amla with a fermented carrier can preserve acceptability while improving micronutrient delivery.

This study demonstrated that inclusion of amla (*Phyllanthus emblica*) in the beverage formulation significantly enhanced its sensory acceptability and nutritional value. Similar findings have been reported that marked improvement in the flavor and overall acceptability of amla-based drinks. (Mishra and Sangma., 2017). The present findings also support earlier observations that amla's rich vitamin C and polyphenolic content improves the nutritional profile of functional beverages while preserving sensory appeal (Devi *et al.*, 2020).

Our drink was further enhanced by the digestive and bioactive properties of ginger, mint, curry leaves, and coriander, which are rich in flavonoids, terpenes, and other secondary metabolites (Maleš *et al.*, 2022). Fermented rice water - rich in probiotics and bioavailable nutrients - served as a low-cost, natural carrier that supports

gut health and overall immunity (Narayanan, 2024) and enhances the palatability of beverage formulations.

Although sensory acceptability of multi-herb, probiotic-enriched drinks is underexplored, our findings help bridge this research gap. The substantial increase in vitamin C, iron, and folic acid underscores amla's contribution to functional beverage development. The slightly higher fiber and polyphenol content further supports its role in gut health and as an anti-inflammatory and antioxidant agent (Avinash *et al.*, 2024).

In addition, a balanced sensory profile is critical for encouraging regular consumption of health-promoting beverages. The drink without amla, while acceptable, lacked the pronounced immunity-boosting benefits that amla provides. This reinforces the value of including traditional, nutritionally dense fruits like amla in functional beverage formulations (Sahrawat and Chaturvedi, 2022). Sensory quality after refrigeration or storage was not assessed. Future work should include post-storage evaluation.

Conclusion

This novel antioxidant-probiotic beverage, formulated with amla, mint, curry leaves, coriander leaves, ginger, and fermented rice water, was found to be highly acceptable and nutrient-dense. Sensory evaluation showed a strong preference for the amla-based drink, which also offered markedly higher vitamin C, iron, and folic acid contents. The findings highlight the potential of utilizing traditional herbs and fruits to enhance the nutritional and functional properties of beverages, thereby providing an affordable, health-promoting alternative to commercial drinks.

Future research should focus on extended shelf-life studies, large-scale consumer acceptability trials, and clinical investigations to substantiate its immune-boosting, gut-supporting, and anti-inflammatory benefits. Given its rich nutritional profile and palatability, this functional beverage can be promoted as a natural and cost-effective nutraceutical option to address micronutrient deficiencies and support general health.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Declaration

Ethical Approval: The study protocol was approved by the Meenakshi Academy of Higher Education & Research Ethical Board in accordance with the relevant guidelines and regulations. (DHR Registration No: EC/NEW/INST/2023/3553) (CDSCO Registration No: ECR/1906/Inst/TN/2023) Reference number: MAHER/IEC/ PhD/124/ APRIL25.

Consent To Participate: Written informed consent was obtained from all individual participants included in the study.

Consent To Publish: Participants provided consent for anonymized data to be used for publication purposes. This study involved a short, voluntary sensory evaluation session of approximately 30 min, wherein participants consumed a minimal quantity (15-30 ml) of a food sample prepared using commonly used Indian ingredients known to be safe for regular dietary consumption. The formulation did not include any allergenic or pharmacologically active ingredients, and the sample volume was significantly below any known thresholds for adverse reactions in healthy individuals. Participants were adults who voluntarily agreed to participate after receiving and signing a Participant Information Sheet (PIS) and Informed Consent Form (ICF), which clearly outlined the purpose of the study, ingredients used, procedures involved, potential risks (none anticipated), and their right to withdraw at any point without consequence. No invasive procedures or identifiable data collection occurred, and the study posed minimal to

no risk to participants. Hence, based on the low-risk nature, voluntary participation, and absence of identifiable data collection, a formal ethical principle was strictly followed.

Abbreviations

TPC - Total Phenolic Content

CFU - Colony-Forming Units

SD - Standard Deviation

FSSAI - Food Safety and Standards Authority of India

APEDA - Agricultural and Processed Food Products Export Development Authority

MoEF - Ministry of Environment, Forest and Climate Change

References

- Anbalagan, C., Nandabalan, S. K., Sankar, P., Dhanasekaran, S., Rajendran, R., Kumarasamy, A., & Muthuramalingam, K. (2024). Postbiotics of naturally fermented symbiotic mixture of rice water aids in promoting colonocyte health. *Biomolecules*, 14(3), Article 344. <https://doi.org/10.3390/biom14030344>
- Anshuman, K. P. (2023). Phytochemicals: An immune booster against pathogens. In S. Pati, T. Sarkar, & D. Lahiri (Eds.), *Recent frontiers of phytochemicals*. Elsevier. <https://doi.org/10.1016/B978-0-443-19143-5.00009-8>
- Avinash, P. G., Hamid, R., Shams, R., Dash, K. K., Shaikh, A. M., Ungai, D., Harsányi, E., Suthar, T., & Kovács, B. (2024). Recent insights into the morphological, nutritional and phytochemical properties of Indian gooseberry (*Phyllanthus emblica*) for the development of functional foods. *Plants*, 13(5), Article 574. <https://doi.org/10.3390/plants13050574>
- Ballester, P., Cerdá, B., Arcusa, R., Marhuenda, J., Yáñez-Gascón, M. J., & López-Román, F. J. (2022). Effect of ginger on inflammatory diseases. *Molecules*, 27(21), Article 7223. <https://doi.org/10.3390/molecules27217223>
- Beekman, T. L., & Seo, H. S. (2023). Analytic-holistic cognitive styles affect consumer responses to food and beverage samples during sensory evaluation. *Current Research in Food Science*, 8, Article 100635. <https://doi.org/10.1016/j.crf.2023.100635>
- Bhalerao, P. P., Mahale, S. A., Dhar, R., Sonawane, S. K., & Goswami, T. K. (2020). Optimizing the formulation for a pomegranate-amlamuskmelon based mixed fruit beverage using sensory analysis and evaluating its thermal stability. *LWT*, 133, Article 109907. <https://doi.org/10.1016/j.lwt.2020.109907>
- Brown, N., John, J. A., & Shahidi, F. (2019). Polyphenol composition and antioxidant potential of mint leaves. *Food Production, Processing and Nutrition*, 1, Article 1. <https://doi.org/10.1186/s43014-019-0001-8>
- Dar, A. H., Kumar, N., Shah, S., Shams, R., & Aga, M. B. (2022). Processing of fruits and vegetables. In *Agro-processing and food engineering: Operational and application aspects* (pp. 535–579). Springer. https://doi.org/10.1007/978-981-16-7289-7_13
- Das, A., Bahadur, V., Prasad, V. M., & Mishra, S. (2021). Standardization, physico-chemical and organoleptic assessment during storage of ready-to-serve blended

- kinnow-aonla beverage. *The Pharma Innovation Journal*, 10(12), 700–706.
- Devi, S., Gupta, E., & Maurya, N. K. (2020). Development of a value-added amla product. *International Archives of Applied Sciences and Technology*, 11(2), 90–93.
- Ganesan, P., Phaiphon, A., Murugan, Y., & Baharin, B. S. (2013). Comparative study of bioactive compounds in curry and coriander leaves: An update. *Journal of Chemical and Pharmaceutical Research*, 5(11), 590–594.
- Gómez de Cedrón, M., Wagner, S., Reguero, M., Menéndez-Rey, A., & Ramírez de Molina, A. (2020). Miracle berry as a potential supplement in the control of metabolic risk factors in cancer. *Antioxidants*, 9(12), Article 1282. <https://doi.org/10.3390/antiox9121282>
- Longvah, T., Ananthan, R., Bhaskarachary, K., & Venkaiah, K. (2017). Indian food composition tables. National Institute of Nutrition, Indian Council of Medical Research.
- Maleš, I., Pedišić, S., Zorić, Z., Elez-Garofulić, I., Repajić, M., You, L., Vladimir-Knežević, S., & Dragović-Uzelac, V. (2022). The medicinal and aromatic plants as ingredients in functional beverage production. *Journal of Functional Foods*, 96, Article 105210. <https://doi.org/10.1016/j.jff.2022.105210>
- Mamoona, T., Rafique, N., Khan, M. Z., Arshad, M. S., Nadeem, M. T., Imran, M., Khan, M. K. I., & Suleria, H. A. R. (2023). Phytonutritional and sensorial assessment of a novel functional beverage formulated from an underutilized fruit of *Carissa spinarum* L. *ACS Omega*, 8(36), 32643–32655. <https://doi.org/10.1021/acsomega.3c03386>
- Marimuthu, M. (2019). Young mothers' acceptance of herbal food supplements: Centred on preventive health behaviour for children. *Journal of Retailing and Consumer Services*, 51, 311–319. <https://doi.org/10.1016/j.jretconser.2019.06.019>
- Medabalimi, K., Kaur, R., & Verghese, M. (2024). Processing effects on selected antioxidant activities and metabolizing enzyme inhibition of *Murraya koenigii* (curry leaves) extracts. *Food and Nutrition Sciences*, 15(6), 470–483. <https://doi.org/10.4236/fns.2024.156031>
- Mihafu, F. D., Issa, J. Y., & Kamiyango, M. W. (2020). Implication of sensory evaluation and quality assessment in food product development: A review. *Current Research in Nutrition and Food Science*, 8(3), 690–702. <https://doi.org/10.12944/CRNFSJ.8.3.03>
- Mishra, L. K., & Sangma, D. (2017). Quality attributes, phytochemical profile and storage stability of functional ready-to-serve drink made from a blend of aloe vera, sweet lime, amla and ginger. *Journal of Food Science and Technology*, 54(4), 761–769. <https://doi.org/10.1007/s13197-017-2516-9>
- Narayanan, K. (2024). Merging the various benefits of the fermentation of rice and rice products: A deep dive into its nutritional benefits, physiological activities, and functional potentials—A review. *Asian Journal of Biotechnology Research*, 27(4S). <https://doi.org/10.53555/AJBR.v27i4S.6035>
- Patel, M., Jaiswal, S., Naik, B., Naik, M., Saxena, D., & Naik, S. N. (2016). Development of antioxidant rich beverage from Mahua (*Madhuca indica*) and Amla (*Emblica officinalis*). *Journal of Scientific and Industrial Research*, 75(1), 35–39.
- Prakash, V., Madhavan, A., Veedu, A. P., Babu, P., Jothish, A., Nair, S. S., Suhail, A., Prabhakar, M., Sain, T., Rajan, R., & Somanathan, P. (2023). Harnessing the probiotic properties and immunomodulatory effects of fermented food-derived *Limosilactobacillus fermentum* strains: Implications for environmental enteropathy. *Frontiers in Nutrition*, 10, Article 1200926. <https://doi.org/10.3389/fnut.2023.1200926>
- Purewal, S. S., Walia, N., & Kaur, P. (2022). Unraveling the effect of storage duration on antioxidant properties, physicochemical and sensorial parameters of ready-to-serve kinnow-amlu beverages. *Applied Food Research*, 2(1), Article 100057. <https://doi.org/10.1016/j.afres.2022.100057>
- Sahrawat, N., & Chaturvedi, N. (2022). Quality evaluation and consumer acceptance test of functional fruit-herb beverages. *Agricultural Reviews*, 43(3), 336–341. <https://doi.org/10.18805/ag.R-2175>
- Salve, R. V. (2020). Studies on development of technology for drying of curry (*Murraya koenigii*) and mint (*Mentha spicata*) leaves and its exploration as a nutraceutical in food products (Doctoral dissertation, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, India).
- Sharma, R., Burang, G., Kumar, S., Sharma, Y. P., & Kumar, V. (2022). Optimization of apricot (*Prunus armeniaca* L.) blended Aloe vera (*Aloe barbadensis* M.) based low-calorie beverage functionally enriched with aonla juice (*Phyllanthus emblica* L.). *Journal of Food Science and Technology*, 59(5), 2013–2024. <https://doi.org/10.1007/s13197-021-05216-z>
- Srilakshmi, B. (2018). Food science (7th ed.). New Age International Publishers.
- Stephen, J., Manoharan, D., & Radhakrishnan, M. (2023). Immune boosting functional components of natural foods and its health benefits. *Food Production, Processing and Nutrition*, 5(1), Article 61. <https://doi.org/10.1186/s43014-023-00178-5>
- Sugumar, J. K., & Guha, P. (2022). Comparative study on the hedonic and fuzzy logic-based sensory analysis of formulated soup mix. *Future Foods*, 5, Article 100115. <https://doi.org/10.1016/j.fufo.2022.100115>
- Talreja, S., Kumari, S., Srivastava, P., & Pandey, S. (2021). A complete pharmacognostic review on amla. *World Journal of Pharmacy and Pharmaceutical Sciences*, 8, 622–637.
- Tewari, R., Kumar, V., & Sharma, H. K. (2023). Thermal and nonthermal processing of an underutilized fruit *Emblica officinalis* (amlu): A sustainable approach. *Sustainable Food Technology*, 1(5), 658–680. <https://doi.org/10.1039/D3FB00058C>
- Torrico, D. D., Mehta, A., & Borssato, A. B. (2023). New methods to assess sensory responses: A brief review of innovative techniques in sensory evaluation. *Current Opinion in Food Science*, 49, Article 100978. <https://doi.org/10.1016/j.cofs.2022.100978>
- Usharani, P., Merugu, P. L., Nitalapati, C., & Kumar, P. V. N. (2019). Evaluation of the effects of a standardized aqueous extract of *Phyllanthus emblica* fruits on endothelial dysfunction, oxidative stress, systemic inflammation and lipid profile in subjects with metabolic syndrome: A randomized, double-blind, placebo-controlled clinical study. *BMC Complementary and Alternative Medicine*, 19, Article 97. <https://doi.org/10.1186/s12906-019-2509-5>
- Vishakha, M. S., & Dunkwal, V. (2021). Formulation of a refreshing drink using dragon fruit (*Hylocereus undatus*) as an immunity booster. *The Pharma Innovation Journal*, 10(3), 80–83. <https://doi.org/10.22271/tpi.2021.v10.i3b.5746>