

Research Article

Production and Quality Evaluation of Herbal Tea Mixtures from *Phyllanthus debilis*, *Osbeckia octandra*, and *Artocarpus heterophyllus* Leaves

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Abstract

Background: This study explored the acceptability and quality of herbal tea blends formulated using powdered leaves of *Phyllanthus debilis*, *Osbeckia octandra*, and *Artocarpus heterophyllus*. Herbal teas are widely consumed for their health benefits, and optimizing their composition is essential for consumer satisfaction and market viability. **Objectives:** The aim was to evaluate sensory attributes, nutrient content, tea quality parameters, and safety aspects of different herbal tea formulations. **Methods:** Tea samples were prepared in various proportions and evaluated by thirty untrained panelists for sensory preferences. Proximate composition, quality indicators, and microbial counts were assessed using AOAC and ISO standard methods. Mineral content was determined via atomic absorption spectrophotometry. **Results:** Dark-colored tea samples were preferred, with a strong positive correlation between redness and color preference. However, bitterness and astringency negatively affected overall acceptability. The *A. heterophyllus* tea had the highest overall acceptability, while teas containing *P. debilis* had the highest color preference. Nutrient analysis showed rich content, though crude fiber and moisture exceeded ideal limits. All microbial counts and heavy metal levels were within safety standards. **Conclusion:** Combining these herbal leaves can improve both acceptability and quality of herbal infusions. With further refinement, these blends hold strong commercial potential.

Keywords: herbal tea, quality parameters, sensory attributes

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1. Introduction

People have been seeking medicine from natural sources to cure diseases since ancient times [1]. Knowledge of exploiting plants to treat different ailments was passed down from generation to generation, both written and verbal. Even today, 80% of people in developing countries use traditional and complementary medicine, particularly herbal therapies, for primary healthcare [2]. In addition, the prophylactic benefits of these herbs are being investigated for potential use in novel pharmaceuticals, nutraceuticals, and functional foods [3]. Functional foods are foods that offer health benefits beyond their nutritional value and they are becoming increasingly popular as a convenient and inexpensive solution to chronic health problems [4]. Herbal tea or tisanes are a type of functional food that has gained considerable interest recently. They are infusions or decoctions made from fresh or dried roots, stems, leaves, fruits, flowers, seeds, bark, or whole plants from one or more herbal tea plant species [5]. The herbal tea market was valued at USD 3,290.17 million in 2021 and is expected to reach the value of USD 5,445.22 million by 2029, at a compound annual growth rate (CAGR) of

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6.50% during the forecast period of 2022-2029 [6]. There are plenty of herbal tea products in the Sri Lankan market and tea is the most preferred functional food product among local consumers [7]. Plants used in Sri Lankan traditional medicine systems are gradually being introduced into the market as herbal teas. However, the scientific investigation of their efficacy, safety, and production qualities is scanty.

Incorporating herbs into food matrices will offer a variety of flavors, aromas, visual appeal, texture and antimicrobial properties to food [8]. Some consumers face difficulties in accepting herbal foods due to characteristic flavors and colors [9]. Therefore, it is vital to evaluate the sensory properties before introducing them to the market place. Measuring tea quality parameters is vital to maintain the briskness/astringency, brightness, and safety of herbal teas.

In Sri Lankan traditional medicine and folk medicine, the whole plant of *P.debilis* or its parts is used to prepare porridge or 'decoction' to treat ailments such as liver complications, diabetes mellitus, and skin diseases. Matured *O. octandra* leaves are consumed as porridges and reported to have antidiabetic and hepatoprotective properties [10-12]. *A. heterophyllus* leaves are utilised in Siddha medicine and folk medicine systems to treat diabetes [13]. This study aimed at producing herbal teas using different proportions of *Phyllanthus debilis*, *Osbeckia octandra*, and *Artrocarpus heterophyllus* leaves and select the best tea sample for mass production based on sensory properties, tea quality parameters, microbial quality, and safety of the herbal tea samples.

2. Methods

2.1. Preparation of herbal tea

Phyllanthus debilis (Niruri), *Artocarpus heterophyllus* (Jak), and *Osbeckia octandra* (Eight Stamen Osbeckia) leaves were screened for production based on their ethnopharmacological importance, Ayurveda claims and previous studies of the same research group (unpublished data). Plants were collected from Balangoda district, Sri Lanka and authenticated by comparison with the voucher specimen deposited at the National Botanical Gardens Peradeniya, Sri Lanka.

Leaves of the plants were separated and air dried in a dry and shady place. Dried leaves were pulverized and sieved (sieve with 600 nm mesh diameter). Powdered plant samples were stored in airtight zip lock bags at -80 °C (Novo-80 freezer) until use. The powdered leaves were mixed at different ratios to prepare the different herbal infusions (Table 1).

Table 1. Composition of herbal tea products

Sample Code	Leaves powder %		
	<i>Phyllanthus debilis</i>	<i>Osbeckia octandra</i>	<i>Artrocarpus heterophyllus</i>
M3	-	100.00	-
M4	66.67	16.66	16.66
M5	50.00	-	50.00
M7	33.33	33.33	33.33
M8	100.00	-	-
M9	-	-	100.00

Leaves powders (individual/mixtures) were dipped in hot water (80 °C) for 10 min until attained room temperature and filtered using Watman no.1 filter papers and the filtrate was separated. Freshly prepared infusions were used for the tests. Proximate composition was tested for the dry powders. Plant powder to water ratio was 1:75.

2.2. Sensory properties

Sensory properties of selected herbal infusions were evaluated using thirty untrained panelists at Sabaragamuwa University of Sri Lanka. Sensory attributes (Color, aroma, astringency, bitterness, aftertaste, and overall acceptability) were evaluated using a five-point hedonic scale test (5=strongly like and 1=strongly dislike).

2.3. Instrumental color values

The colour of the samples was measured using a Hunter Lab colour meter (CR 400, Conika Minolta, Japan). Measurements were taken directly at three different locations, after standardization with a white calibration plate ($L^* = 94.12$, $a^* = 0.29$, and $b^* = 2.73$). Colour was expressed in Hunter Lab units L^* , a^* and b^* , where

L* indicates lightness, a* indicates hue on a green (–) to red (+) axis, and b* indicates hue on a blue (–) to yellow (+) axis [14].

2.4. Proximate composition, tea quality parameters and mineral content

The crude protein, crude fat and total fibre content were determined in dry basis by using AOAC Method 920.152, 920.39, and 991.43, respectively [15, 16]. Loss in mass at 103 °C, total ash, and acid-insoluble ash contents were determined as per the methods described in ISO 1573:1980 [17]. ISO 1575:1987, and ISO 1577:1987, respectively [18]. Loss in mass at 103 °C (moisture content) was determined after oven drying to a constant weight at 103 °C. Total ash content was obtained by incinerating the sample in a muffle furnace (Obersal) at 550 °C for five hours until whitish gray ash was obtained. Concentration of major elements (Na, K) and trace elements (Ni, Zn, Mn, Cu, Pb, Cd) of selected tea mixtures were measured as per the method utilized by Perera et al. (2020) with slight modifications using Atomic Absorption Spectrophotometer (AAS) (Varian 240FS) [19].

2.5. Microbial quality evaluation

Aerobic plate count, yeast and mould, and *E coli* counts were determined by ISO 4833:2013, ISO 21527-2:2008, and ISO 7251:2005, respectively [20].

2.6. Statistical analysis

Statistical analysis of the results was performed using Minitab 17 software. The significance of the difference of tested parameters among samples was evaluated using one-way ANOVA method and the Tukey's test, at a significance level of $\alpha = 0.05$. The relationship between sensory and instrumental data was explored through calculating the Pearson's correlation coefficient at $p \leq 0.05$.

3. Results

3.1. Sensory properties of selected herbal tea infusions

Sensory attributes of tea infusions occurred due to their chemical compositions [21]. As different herbs have diverse chemical compositions, the consumer preference for the selected samples is significantly different except for the attribute aroma preference ($p=0.063$) (Table 2). Even though phytochemicals such as phenols, flavonoids, isoflavones, terpenes, and glucosinolates have numerous health benefits, most of them have a bitter, acrid, or astringent taste and therefore aversive to the consumer [22]. Astringency usually involves the formation of aggregated precipitates between tannins or polyphenols and proteins in the saliva [23]. However, some findings revealed bitter phytochemicals have a higher probability of exerting health benefits [24].

In the study, M7 and M9 obtained highest preference for bitterness and M7 obtained highest preference to astringency (Table 2) (Figure 1). Consumers much prefer for those samples which having less bitterness and astringency. Overall acceptability also highest in these samples (M9 and M7) which demonstrated bitterness and astringency have a considerable impact in consumer preference for the herbal teas. Sample M8 have the least bitterness and aftertaste preference and overall acceptability while M3 have least astringency preference. By mixing the herbs, overall acceptability and the preference for color, bitterness, astringency and aftertaste can be increased. Hence, polyherbalism have advantageous effect on product optimization as well.

Table 2. Average rank values of consumer preference data

Sample	Color	Aroma	bitterness	Astringency	After taste	Overall acceptability
M3	2.50±0.99 ^b	2.94±1.21 ^a	2.89±0.78 ^{ab}	2.56±1.20 ^b	2.89±1.28 ^{ab}	2.78±1.00 ^{ab}
M4	4.17±0.79 ^a	3.61±0.78 ^a	2.89±1.07 ^{ab}	2.94±0.80 ^{ab}	2.89±0.96 ^{ab}	2.94±0.96 ^{ab}
M5	3.61±1.04 ^a	3.44±0.78 ^a	3.28±1.28 ^{ab}	3.22±0.88 ^{ab}	3.22±1.22 ^{ab}	3.33±1.03 ^{ab}
M7	3.56±0.78 ^a	3.33±0.84 ^a	3.44±0.96 ^a	3.56±0.78 ^a	3.22±0.94 ^{ab}	3.61±0.85 ^a
M8	4.17±1.04 ^a	3.61±0.85 ^a	2.39±1.04 ^b	2.94±1.06 ^{ab}	2.44±0.98 ^b	2.56±0.98 ^b
M9	3.33±0.91 ^{ab}	2.94±0.73 ^a	3.72 ±0.83 ^a	3.33±0.91 ^{ab}	3.61 ±1.09 ^a	3.67 ±1.03 ^a
P value	0.000	0.063	0.002	0.036	0.041	0.002

Mean ± SE (n=30). Values followed by different letters in the same column are significantly different ($p < 0.05$) according to Tukey's test

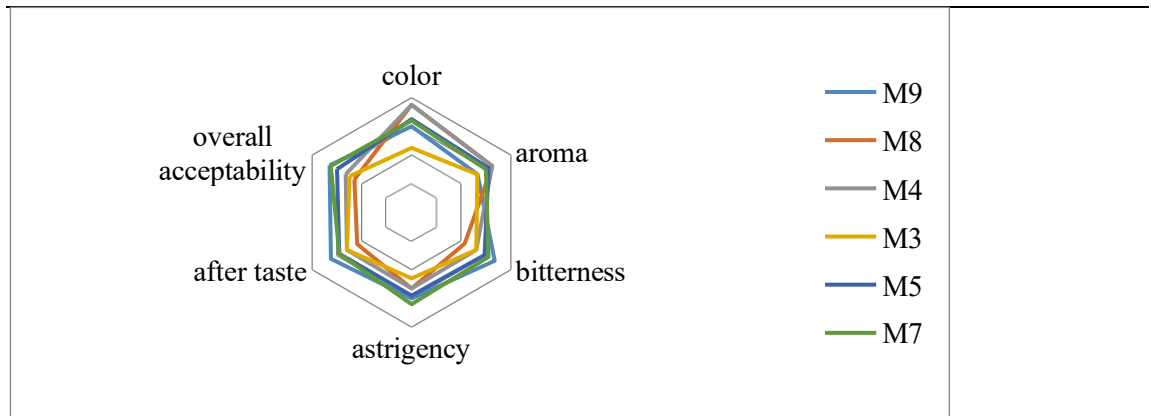


Figure 1. Average rank values of consumer preference data

Food color have largely impact to the purchasing decision of consumer [21]. In here, a correlation analysis was conducted to measure the strength and direction of association between sensory data and instrumental color values. The results showed that statistically significant negative correlation among color preference and both L^* (whiteness) and b^* (yellowness) values while the correlation was positive for the color preference and a^* (redness) value (Table 4). That means darker the tea color (redness increases, whiteness, and yellowness decreases), color preference of the consumer increased. Table 3 showed the lightness (L^*) highest in M3 and lowest in M8. By mixing the herbs in different propositions the color values can be adjust.

Table 3. Instrumental color values of the samples

Sample	L^*	a^*	b^*
M3	25.72±0.51 ^a	-0.17±0.01 ^c	11.28±0.06 ^a
M4	13.40±0.03 ^d	4.15±0.01 ^b	2.59±0.01 ^e
M5	15.66±0.19 ^c	3.05±0.02 ^c	7.41±0.05 ^c
M7	15.56±0.19 ^c	4.41±0.14 ^b	6.73±0.03 ^d
M8	13.74±0.20 ^d	5.38±0.03 ^a	1.81±0.04 ^f
M9	18.32±0.01 ^b	1.19±0.16 ^d	9.15±0.03 ^b
<i>p</i> value	0.001	0.001	0.001

Based on the sensory quality attributes, particularly the color values, M4, M5, and M8 were selected for further product quality tests (Table 4).

Table 4. Linear correlation between sensory and instrumental color parameters

Parameters	Color	Overall acceptability
Lightness	-0.926*	-0.164
a^* coordinate	0.920*	-0.18
b^* coordinate	-0.876*	0.166

* Correlations are statistically significant ($P < 0.05$)

3.2. Proximate composition and tea quality parameters

The samples studied significantly ($p < 0.05$) differed in all the proximate parameters. Study of Rehman et al. (2002) suggested 1-2% of protein and 0.95-1.62% of fat contents for better quality of tea samples [25]. In contrast, in these herbal mixtures, comparatively high fat contents (4.80-6.25%) were observed. Highest crude protein and fat content was observed in sample M4. Crude fiber contents of these herbal teas were slightly exceeding the maximum limit 16.50%. Crude fiber content highest in M5 may be due to high fiber content of *A. heterophyllus*. The moisture contents of the samples studied were above the standard value of 7% and this may have a negative impact on the shelf life of the samples. Total ash and acid insoluble ash contents are in

the standard range [26]. Biomolecules in herbs (phytochemicals, protein and carbohydrate) are responsible for organoleptic, gustatory and medicinal properties of tea. Extraction of these molecules to the tea brew is depend on various parameters such as caffeine content, boiling time and temperature This aspect also should consider in herbal tea production [25-27].

Table 5. Proximate composition and tea quality parameters

Parameter	Dry basis %			Required maximum limit (%)*
	Mix 4	Mix 5	Mix 8	
Crude protein	2.91±0.11 ^a	1.65±0.04 ^b	2.02±0.01 ^b	-
Fat	6.25±0.25 ^a	5.33±0.00 ^b	4.80±0.07 ^b	-
Crude fiber	20.67±0.33 ^b	36.33±2.03 ^a	18.67±1.76 ^b	16.50
Moisture	13.83±0.17 ^b	12.83±0.17 ^a	11.17±0.17 ^a	7.00
Total ash	7.08±0.68 ^a	6.77±0.65 ^a	8.24±0.74 ^a	04-Aug
Acid insoluble ash	0.56±0.02 ^b	0.09±0.01 ^c	1.20±0.05 ^a	1.0

*Source: [26]

3.3. Minerals content

Foods and beverages are key route for human to expose metals. Some studies showed herbal teas contain higher heavy metal contents than traditional teas [28]. As these are totally new formulations and the ingredients are not frequently use by the consumers, it is vital to test for the heavy metal contents. Table 6 showed the results for the heavy metal content of selected tea infusions. Accordingly, Zn, Cd, Cu, and Pb levels were within the standard limits for herbal teas. Other heavy metals also were in minute amounts. K and Na are highest in sample M4.

Table 6. Mineral content of selected polyherbal compositions

Parameter	ppm			Maximum limit * WHO	FDA
	M4	M5	M8		
Na	0.340±0.00 ^a	0.297±0.00 ^c	0.32±0.02 ^b	-	
K	211.66±0.58 ^a	155±1.00 ^c	185.66±2.08 ^b	-	
Cu	0.032±0.00 ^a	0.023±0.00 ^b	0.030±0.00 ^a	20.00	20.00
Mn	1.242±0.00 ^c	2.058±0.01 ^a	2.002±0.00 ^b	-	
Zn	0.014±0.00 ^c	0.115±0.00 ^a	0.1023±0.00 ^b	50.00	50.00
Cd	0.006±0.00	BDL	BDL	0.20	0.30
Pb	0.03±0.00 ^a	0.01±0.00 ^b	0.01±0.00 ^b	10.00	10.00
Ni	BDL	BDL	BDL	-	

*Source: [29]

BDL-Bellow detected limit. WHO-World Health Organization, FDA- US Food and Drug Administration.

3.4. Microbial quality of herbal infusions

Poor agricultural, collection, handling and storage practices of herbal products may leads to poor microbial quality. Insufficient drying leads to increased level of microbial contamination, hence, drying time and temperature is a critical control point in herbal tea production. Some studies unveiled that market available herbal teas were contaminated with both bacteria and fungi at various levels may be potential risk for the regular consumer arising public health issues [30-31].

Table 7 showed the microbiological analysis for the tea mixtures soon after the production. Total viable count of all samples was less than 10⁴ cfu/g and yeasts and moulds were within the limits. *E. coli* was not detected. *P. debilis*, *O. octrandra*, *A. heterophyllus* were reported to have antimicrobial properties against *Salmonella typhi* and *Escherichia coli* [32]. This antimicrobial property may be reason for the higher microbial quality of tea mixtures. Yet, suitable packaging materials and storing conditions need to select to ensure the

keeping quality of the product at mass scale production.

Table 7. Microbial quality of herbal tea infusions

Type of Micro-organisms	M4	M5	M8	Maximum limits*
Yeasts, cfu/g	<100	<100	<100	1.0×10^2
Moulds, cfu/g	<100	<100	<100	1.0×10^3
E.coli, cfu/g	ND	ND	ND	Absent
Total Viable Count (Aerobic colony count), cfu/g	1.3×10^3	2.0×10^3	2.3×10^3	2.0×10^5

*[26]; ND-not Detected

Mean is average of two replicates and express as CFU/g. Mean with different letters in the same row are significantly different $P \leq 0.05$.

4. Discussion

This study evaluated the impact of combining *Phyllanthus debilis*, *Osbeckia octandra*, and *Artrocarpus heterophyllus* on the sensory, nutritional, and microbiological qualities of herbal teas. Sensory analysis showed that consumer preferences varied significantly across the tea samples, particularly in attributes such as color, bitterness, astringency, and aftertaste [26-30]. Aroma was the only attribute without a statistically significant difference. Samples with higher redness values, such as M7 and M9, were favored, supporting the idea that visual appeal, particularly darker tea color, influences consumer preferences. However, excessive bitterness and astringency were found to reduce overall acceptability, indicating the importance of taste balance in product development [26-28].

Instrumental color analysis revealed a strong positive correlation between redness and color preference, reinforcing the role of appearance in sensory appeal. The herbal combinations enabled a balance between visual and flavor characteristics, aligning with the concept of polyherbalism used in traditional systems like Ayurveda [30-32].

Nutritional analysis indicated that the tea blends were rich in proteins and fats, though crude fiber and moisture content were slightly above recommended levels, which may affect product stability. Mineral content was within safe limits, and microbial analysis confirmed that all samples met health and safety standards. These findings suggest that with appropriate formulation, polyherbal teas offer promising potential as both functional and marketable beverages [31].

The results showed sensory qualities, nutrition composition, and tea quality parameters of herbal teas can alter by mixing different herbs. This concept is utilized in Ayurveda to enhance the efficacy of herbal treatments, called polyherbalism. However, the herbal-herbal interactions should be taken into account in such modifications. The sensory evaluation demonstrated samples with high redness (a^*) were much preferred by the consumers. Yet, the highest bitterness and astringency reduced the overall acceptability. Overall acceptability scores were highest for *A. heterophyllus* tea (M9) with less astringency and bitterness. However, the color preference was highest in *P. debilis* tea (M8) and mix of *P. debilis* and *O. octandra* (M4). The tea samples were rich in nutrients. Heavy metal concentrations and microbial counts lay within the standard limits stipulated by WHO and FDA. After accessing the functional properties, these novel tea mixtures can thrive commercially in the tea market.

5. Conclusion

The study concludes that blending different herbal components such as *Phyllanthus debilis*, *Osbeckia octandra*, and *Artrocarpus heterophyllus* can significantly enhance the sensory quality and nutritional value of herbal teas. Samples with higher redness were more appealing to consumers, although excessive bitterness and astringency reduced overall acceptability. Among the blends, *A. heterophyllus* tea showed the highest overall acceptability due to its milder taste, while the most visually preferred samples were those containing *P. debilis*. All tea samples demonstrated acceptable levels of heavy metals and microbial content, meeting international safety standards. This suggests that with appropriate formulation and consideration of herb-herb interactions, these polyherbal teas have strong potential for commercial success in the herbal beverage market.

6. Data Availability Statement

The datasets generated and analyzed during the current study are not publicly available due to privacy and ethical considerations but are available from the corresponding author upon reasonable request.

7. Ethical Statement

This study was approved by the Research Ethics Committee of University of Sri Jayewardenepura.

8. Author Contributions

All authors contributed to the design and implementation of the research, data analysis, and finalizing the manuscript. The researches would like to acknowledge Dr. Namal Perera for the directions given in the experiments and Ms. Sadhana Gayathri and Ms. Sumudu Arundathi for assist in research activities.

9. Funding

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10. Conflict of Interest

Authors declares no conflict of interest.

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