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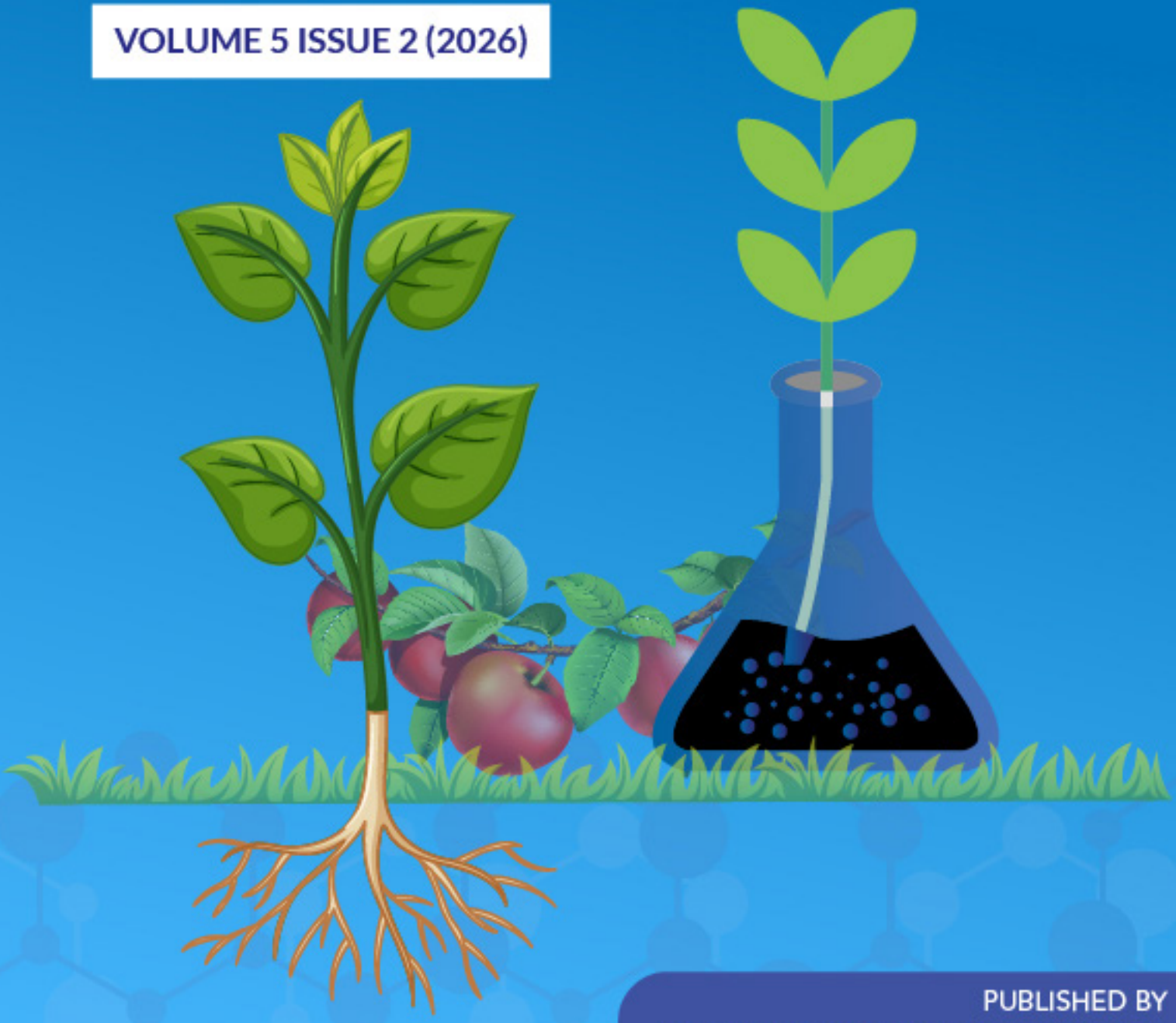

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Physicochemical Properties, Colour and Sensory Evaluation of a Functional Tea Infuse from Pawpaw Leaves, Pawpaw Seeds, Lemon Grass and Negro Pepper

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ABSTRACT

Papaya (Carica papaya) commonly known as pawpaw, is a tropical fruit renowned for its rich nutritional profile and medicinal properties. Both the leaves and seeds of the papaya plant have been used traditionally in various cultures for their therapeutic benefits. Papaya leaves are known to contain significant amounts of vitamins, minerals, and antioxidants, which contribute to their use in treatments for ailments such as dengue fever and diabetes. The seeds, although less commonly used, have shown potential in combating parasites and supporting liver health due to their phytochemical content. The raw materials pawpaw leaves, pawpaw seeds, negro pepper were dried at a controlled temperature of 50°C. After drying, the materials were ground into a fine powder using a laboratory grinder. They were mixed in different proportions [A;85 % PLV, 5% PSD, 5% LG, 5% NP B;80 % PLV, 5% PSD, 5% LG, 10% NP C; 75 % PLV, 5% PSD, 5% LG, 15% NP D;70 % PLV, 5% PSD, 5% LG, 20% NP] to create the herbal tea blend. The infused herbal tea samples were analyzed for physicochemical, color and sensory properties. All samples recorded a pH range from 4.98 to 5.155, indicating that they are slightly acidic. There were no significant differences in the pH of the samples. Ash content decreased from 13.346% in Sample A to 11.872% in Sample C, suggesting variations in mineral content based on the proportion of negro pepper. Total soluble solids values increased from 124.08 mg/L in Sample A to 141.65 mg/L in Sample D, indicating that higher negro pepper content correlates with increased solubility of solids. Extractive matter content ranges from 12% to 14%, with Sample C having the highest value. The color properties of the infused herbal tea include L values decrease from 26.12 in Sample A to 21.83 in Sample C, indicating a trend towards darker tea as the proportion of negro pepper increases. All samples exhibit negative values for the a* component, indicating a greenish hue. The values declined from 2.82 in Sample 1 to 4.52 in Sample C, suggesting a shift towards a greener tint with increased negro pepper. The b* values show an increase from 27.05 in Sample A to 36.86 in Sample C, indicating that the tea becomes more yellow as the negro pepper content rises. The result of the sensory evaluation shows that sample D had the highest colour of 8.38 which indicates a vibrant, appealing hue that suggests freshness and quality. The highest score in overall acceptability was observed in sample D (8.24), this suggests that it is the most preferred sample, likely due to its superior scores across sensory attributes. Consumers tend to prefer products that deliver a harmonious sensory experience. A functional tea with acceptable sensory characteristics has been produced from underutilized plant materials some of which were regarded as waste.

INTRODUCTION

The growing interest in functional foods and beverages has driven considerable research into the development of products that offer health benefits beyond basic nutrition. Among these, herbal teas have gained popularity for their purported therapeutic properties, bioactive compound content, and natural composition (Ishwah *et al.*, 2022). Instant herbal teas, in particular, are gaining traction due to their ease of preparation, extended shelf life, and the retention of phytochemical properties through innovative drying and extraction techniques (kabbashi *et al.*, 2026; Lin *et al.*, 2020). These beverages not only satisfy the growing demand for convenience but also align with the global shift toward plant-based wellness solutions (Imohiosen, 2023).

Papaya (Carica papaya), commonly known as pawpaw, is a tropical plant revered not only for its sweet, fleshy fruit but also for the medicinal potential of its non-fruit parts (Adeoye *et al.*, 2024; Sundar *et al.*, 2021). Traditionally utilized in African, Asian, and South American cultures, both papaya leaves and seeds have demonstrated significant pharmacological promise. The leaves are a rich source of phenolic compounds, flavonoids, and vitamins A, C, and E, which contribute to their antioxidant, anti-inflammatory, and antidiabetic activities. They have also been extensively studied for their role in platelet regeneration, particularly in the management of dengue fever (Adesola *et al.*, 2020; Do *et al.*, 2024). The seeds, often discarded as waste, are emerging as a potent nutraceutical resource, exhibiting antiparasitic, hepatoprotective, and antimicrobial effects due to the presence of alkaloids, carpaine, and benzyl isothiocyanate (Edeoga *et al.*, 2005;

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Kanadi *et al.*, 2021) .

Incorporating Xylopia aethiopica commonly known as Negro pepper into this formulation enhances not only the therapeutic profile but also the sensory appeal of the infusion (Fategbe *et al.*, 2021). Although sometimes misunderstood as a spice alone, Negro pepper is a flowering plant belonging to the Annonaceae family, native to West Africa and widely used in both culinary and medicinal contexts. It is rich in essential oils, alkaloids, and diterpenes that exhibit analgesic, anti-inflammatory, and antioxidant activities (Akande *et al.*, 2014). Furthermore, Negro pepper has been shown to support respiratory health, act as a digestive aid, and even demonstrate aphrodisiac properties attributes that have kept it embedded in traditional African pharmacopoeia for generations (Ahmed *et al.*, 2025; Arhin *et al.*, 2025).

Lemongrass (Cymbopogon citratus), another crucial component of this blend, contributes a refreshing citrus aroma along with a cocktail of bioactives such as citral, myrcene, and limonene. These compounds are known for their antimicrobial, anxiolytic, and anti-hyperlipidemic properties (Mukarram *et al.*, 2021). The infusion of lemongrass not only improves flavor and aroma but also adds to the beverage's functional profile, making it more appealing to health-conscious consumers.

Herbal teas have long been consumed for their perceived health benefits, aromatic properties, and therapeutic potential. In recent years, increasing consumer preference for natural and functional beverages has intensified research into novel herbal infusions with rich phytochemical profiles and appealing sensory qualities (Abdullah *et al.*, 2023; Kauser-Ul-Alam *et al.*, 2025). Among the diverse array of botanicals, Carica papaya (pawpaw) leaves and seeds, Cymbopogon citratus (lemon grass), and Xylopia aethiopica (Negro pepper) are notable for their antioxidant, antimicrobial, and anti-inflammatory properties (Ayaz *et al.*, 2026; Fetse *et al.*, 2016).

Despite the individual medicinal properties of these plants, there is a dearth of scientific research exploring the physicochemical characteristics and color attributes of their combined infusions as a functional herbal tea. Most existing studies have focused either on isolated extracts or the pharmacological effects of the individual plants, with limited attention to their synergistic interactions in beverage form or the influence of preparation methods on physicochemical and aesthetic qualities such as pH, total soluble solids, turbidity, color intensity, and browning index (Altiok and Kasapoglu, 2026; Choudhary *et al.*, 2025).

Color, in particular, is a crucial sensory parameter that significantly affects consumer perception and acceptability of herbal beverages, yet this aspect remains underreported for novel combinations like pawpaw leaves and seeds with lemon grass and Negro pepper. Furthermore, the optimization of infusion conditions to balance therapeutic value with consumer appeal is an area that remains largely unexplored (Spence, 2015).

Furthermore, comprehensive studies on the physicochemical properties and color stability of these instant herbal teas are crucial for ensuring product quality and consumer acceptance (Zhong *et al.*, 2023). Understanding these properties can lead to better formulation strategies that maintain the stability and efficacy of the active compounds, ensuring that the health benefits are preserved throughout the product's shelf life. Additionally, addressing the sensory properties, such as color, is important for consumer appeal, as these attributes significantly influence purchasing decisions (Deha *et al.*, 2024; Sharaf *et al.*, 2021).

MATERIALS AND METHODS

Materials

The primary plant materials for this study are pawpaw (Carica papaya) leaves, pawpaw seeds, lemon grass and negro pepper (Xylopia aethiopica). These materials was sourced from the LAUTECH Teaching and Research Farm and also local market in Ogbomosho, Oyo State, Nigeria, ensuring they were fresh and of high quality.

Samples Preparation

For this study, fresh pawpaw leaves and seeds, along with lemon grass and negro pepper, were used. The plant materials were washed thoroughly under running water to remove dirt and debris. After cleaning, the pawpaw leaves, seeds, lemon grass and negro pepper were oven dried at a controlled temperature of 40-50°C (Adesola *et al.*, 2020; Akande *et al.*, 2014).

After drying, the materials were ground into a fine powder using a laboratory grinder. The powdered pawpaw leaves, seeds, lemon grass and negro pepper were mixed in different proportions to create the herbal tea blend (Table 1). These blends were further processed into instant tea granules. The final products were stored in airtight containers under controlled conditions to protect it from moisture, light, and other environmental factors that could degrade its quality (Choudhary *et al.*, 2025).

Brewing

Table 1: Infused Herbal Tea Formulation

Samples	Pawpaw leaves powder (%)	Pawpaw seeds powder (%)	Lemon grass powder (%)	Negro pepper powder (%)
A	85	5	5	5
B	80	5	5	10
C	75	5	5	15
D	70	5	5	20

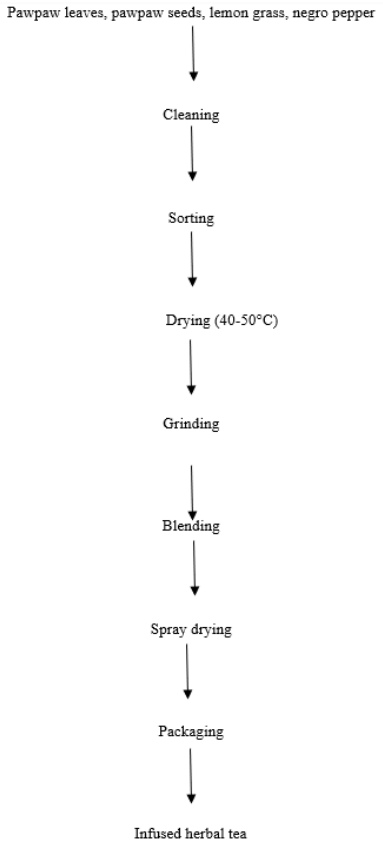

Figure 1: Flow chart of the production of infused herbal tea (Choudhary *et al.*, 2025).

A precise amount of the instant herbal tea blend (e.g., 5 grams) was measured and placed into a clean, heat-resistant cup. Hot distilled water, preheated to a temperature of approximately 90-95°C, was poured over the tea blend, afterwards, the mixture was stirred thoroughly for about 1-2 minutes to ensure complete dissolution of the powder. The brewed tea was allowed to steep for an additional 5 minutes before analysis to ensure that all bioactive compounds are fully extracted (Liu *et al.*, 2024).

Physicochemical Analysis

PH Measurement

According to Kizzie-Hayford (2024), the pH of the brewed tea was measured using a calibrated pH meter. The pH meter was calibrated using standard buffer solutions (pH 4.0, 7.0, and 10.0) before each measurement session. A sample of the brewed tea was taken, and the pH probe was immersed in the sample. The pH value was recorded once the reading stabilizes.

Total Soluble Solids (TSS)

According to Karaituma *et al.* (2025), the total soluble solids (TSS) content of the brewed tea was determined using a refractometer. The refractometer was calibrated using standard calibration solutions. A drop of the brewed tea was placed on the refractometer prism, and the TSS value was read directly from the instrument. The results was expressed in degrees Brix (°Brix).

Electrical Conductivity (EC)

According to Liu *et al.*(2024), the electrical conductivity (EC) of the brewed tea was measured using a conductivity meter. The conductivity meter was calibrated with standard solutions of known conductivity. A sample of the brewed tea was placed in a clean beaker, and the conductivity probe was immersed in the sample. The EC value was recorded once the reading stabilizes.

Colour Evaluation

According to Clydesdale (1993), the color evaluation of the brewed tea was conducted using a colorimeter. The colorimeter was calibrated with standard color reference tiles before each measurement session. A sample of the brewed tea was placed in a clean cuvette, and the colorimeter probe was immersed in the sample. The color values, typically expressed in the CIELAB color space (L*, a*, b*), was recorded once the reading stabilizes.

Determination of Ash Value

According to Lin *et al.*(2020), the determination of ash value in the brewed tea was conducted using a muffle furnace. The tea sample was dried to a constant weight in an oven at 105°C. After drying, the sample was placed in a pre-weighed crucible and incinerated in the muffle furnace at 550°C until a white or light gray ash is obtained. The crucible was cooled in a desiccator, and the ash content was determined by weighing the residue.

Evaluation of extractive matter

According to Abdullah *et al.* (2023), the evaluation of extractive matter in brewed tea was conducted by determining the soluble solids content. The process involves taking a known weight of the dried tea sample, boiling it with distilled water, and then filtering the solution.

The filtrate was evaporated to dryness and the residue weighed to determine the extractive matter. This method ensures that the total soluble content, which includes essential oils, resins, and other bioactive compounds, is accurately quantified.

Statistical Analysis

Data was analyzed statistically using analysis of variance (ANOVA). Results was also analyzed using SPSS statistical package (Version 17.0) analysis of variance (ANOVA), Duncan multiple range test and mean ± standard deviation was chosen to determine any significant difference among the samples

RESULTS AND DISCUSSION

Physicochemical Properties of Infused Herbal Tea

The results of the physicochemical properties of infused herbal tea is presented in Table 2. The pH values of the herbal teas ranged from 4.98 to 5.16. These values indicate that the infusions are slightly acidic. The slightly acidic

nature can enhance the solubility of various bioactive compounds, such as flavonoids and phenolic acids, making them more bioavailable. The pH range aligns with findings from Siriwardhana *et al.* (2019), which noted that acidic environments favor the stability and extraction efficiency of phytochemicals in herbal infusions. This acidity can also influence the flavor profile, making the teas more palatable. A study by Abdullah *et al.* (2023) found similar pH values (4.5 to 6.0) and TSS levels in herbal infusions from various leaves, reinforcing the results obtained in this study.

The ash content varied from 11.845% to 13.365%. Ash content serves as an indicator of mineral richness. The observed values suggest a moderate concentration of minerals, including potassium, calcium, and magnesium, which are essential for various physiological functions. Edeoga *et al.* (2005) indicated that herbal teas with high ash content can provide significant dietary minerals, contributing to overall health. This mineral profile supports the idea that these teas can serve as functional beverages, promoting health through mineral intake. Edeoga *et al.*

(2005) discussed the importance of mineral content in herbal teas, aligning with the moderate ash content found in the current study.

Table 2: Physico-Chemical Properties of Infused Herbal Tea

Samples	pH	Ash (%)	Total soluble solid (mg/L	Electrical conductivity (µs/cm)	Extractive Matter (%)
A	4.98 ± 0.00a	13.346 ± 0.027c	124.08 ± 0.02a	12.19 ± 0.01a	13 ± 0.00b
B	5.05 ± 0.01a	12.515 ± 0.008b	137.23 ± 0.00b	13.39 ± 0.01b	13 ± 0.00b
C	5.155 ± 0.01a	11.872a ± 0.038	132.71 ± 0.01b	12.52 ± 0.00a	14 ± 0.00c
D	5.07 ± 0.00a	12.329 ± 0.012b	141.65 ± 0.01c	12.95 ± 0.00a	12 ± 0.00a

Mean in the same columns with different superscript were significantly different (P<0.05).

Keys:

A= 85 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 5% Negro pepper

B= 80 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 10% Negro pepper

C= 75 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 15% Negro pepper

D= 70 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 20% Negro pepper

TSS values ranged from 124.09 mg/L to 141.65 mg/L. TSS measures the concentration of dissolved substances, including sugars, organic acids, and other solubles. Higher TSS values indicate a richer flavor and potential health benefits. The presence of these solubles can enhance the antioxidant capacity of the teas. Research by Abdullah *et al.* (2023) highlights that higher TSS values correlate with improved sensory attributes and health-promoting properties.

Electrical conductivity ranged from 12.18 to 13.40 µs/cm. Low electrical conductivity suggests a low concentration of dissolved ions, which corresponds with the slightly acidic nature of the infusions. This low ion concentration is typical for herbal teas, reflecting the limited mineral leaching from the plant materials. The conductivity measurements support the understanding that the infusions contain primarily organic compounds rather than a high concentration of salts (Park and Lee, 2025).

Extractive matter percentages were consistent, ranging from 12% to 14%. The extractive matter represents the total soluble components extracted from the herbal materials during infusion. Higher percentages indicate effective extraction, which is crucial for delivering the health benefits associated with herbal teas. This consistency suggests that the brewing process is efficient in drawing out bioactive compounds. Extractive matter has been linked to the antioxidant potential of herbal infusions, supporting their use in promoting health (Abdullah *et al.*, 2023).

Color Properties of Infused Herbal Tea

The results of the color evaluation of the infused herbal tea is presented in Table 2.The color evaluation of herbal teas is essential not only for aesthetic appeal but also for consumer acceptance and perceived quality. The lightness values (L values) ranged from 21.54 to 26.37. Higher L values indicate lighter colors, which are often more appealing to consumers. The brightness of the infusions can be attributed to the specific plant materials used.

Research indicates that color significantly influences consumer preferences and perceptions of quality in herbal teas (Zhong *et al.*, 2023).

The a values ranged from -4.71 (green) to -1.03 (less green), while b values ranged from 25.58 (less yellow) to 38.71 (more yellow). The negative a values indicate a dominance of green tones, characteristic of many herbal teas, particularly those derived from leaves. The positive b values suggest a yellow hue, which adds to the visual appeal. This combination of color characteristics suggests freshness and quality, which can enhance consumer acceptance. Spence (2015) emphasized that color is a significant factor in consumer acceptance of herbal teas, echoing the results regarding the L, a, and b values observed in this study.

Sensory Evaluation of Infused Herbal Tea

Table 3: Color Properties of Infused Herbal Tea

Samples	L*	A*	B*
A	26.12 ± 0.14	-2.82 ± 0.15	27.05 ± 0.31
B	23.72 ± 0.67	-3.10 ± 0.43	32.65 ± 2.28
C	21.83 ± 0.26	-4.52 ± 0.22	36.86 ± 1.45
D	26.24 ± 0.15	-1.04 ± 0.01	26.58 ± 0.85

Mean in the same columns with different superscript were significantly different (P<0.05).
Keys:
A= 85 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 5% Negro pepper
B = 80 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 10% Negro pepper
C = 75 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 15% Negro pepper
D = 70 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 20% Negro pepper
L Lightness A* Red or green axis B*- Yellow or blue axis*

The results of the sensory analysis of the infused herbal tea is presented in Table 4. The values obtained for appearance, flavor, aroma, taste, after-taste, color and overall acceptability ranged from 6.91 to 829, 5.57 to 8.00, 5.81 to 7.52, 4.76 to 6.57, 4.17 to 6.52, 6.68 to 8.38 and 6.37 to 8.24 respectively. Sample D (8.29) scored the highest for appearance, indicating that its visual quality is particularly appealing. The brightness and clarity likely evoke freshness, which is crucial for attracting consumers (Coelhos *et al.*, 2016). A visually appealing product can enhance perceived quality, leading to increased purchase likelihood. The result obtained for sample A (7.14) shows a consistent and acceptable appearance but lacks the vibrant quality of Sample D. Visual uniformity can suggest stability in quality but may not excite consumer interest compared to more colorful options.

Sample C (7.15) stands out with the strongest flavor profile. Herbal teas that deliver a robust flavor are often preferred, as flavor intensity correlates with consumer satisfaction (Ahmed *et al.*, 2025). The herbal blend in Sample C likely resonates well with those seeking a rich taste experience.

The lowest score observed in sample B (5.57) for flavor suggests a lack of depth, which can significantly impact consumer appeal. Studies show that flavor is a primary driver of repeat purchases. A subdued flavor can lead to consumer disappointment and reduced likelihood of re-purchase.

Table 4: Sensory Properties of Infused Herbal Tea

Sample	Appearance	Flavor	Aroma	Taste	After-taste	Color	Overall Acceptability
A	7.14 ± 0.00b	6.57 ± 0.30b	5.81 ± 0.64a	5.00 ± 0.38b	4.17 ± 0.03a	7.14 ± 0.56b	6.37 ± 0.25a
B	6.91 ± 0.57a	5.57 ± 0.75a	6.18 ± 0.71b	4.76 ± 0.60a	4.57 ± 0.20b	6.68 ± 0.68a	6.48 ± 0.18a
C	6.95 ± 0.21a	7.15 ± 0.24c	6.50 ± 0.32c	5.67 ± 0.58c	5.33 ± 0.15c	7.71 ± 0.33c	7.20 ± 0.51b
D	8.29 ± 0.32c	8.00 ± 0.51d	7.52 ± 0.43d	6.57 ± 0.29d	6.52 ± 0.14d	8.38 ± 0.14d	8.24 ± 0.11c

Mean in the same columns with different superscript were significantly different (P<0.05).
Keys:
A= 85 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 5% Negro pepper
B= 80 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 10% Negro pepper
C = 75 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 15% Negro pepper
D = 70 % Pawpaw leaves, 5% Pawpaw seeds, 5% Lemon grass, 20% Negro pepper

Sample D (7.52) has highest aroma score suggesting an inviting scent that enhances the overall sensory experience. Aroma plays a critical role in flavor perception; when consumers associate pleasant aromas with positive experiences, it can significantly enhance overall enjoyment. While the score observed in sample A (5.81) is moderate, it indicates that aroma is a weaker point for this sample. A less pronounced aroma may detract from initial appeal, as the olfactory experience is crucial in the consumption of beverages (Coelho *et al.*, 2016).

The high taste score observed in sample D (6.57) indicates a well-balanced and pleasing flavor profile, crucial for consumer satisfaction. Well-rounded taste profiles can elevate overall enjoyment and are critical for positive product ratings (Guo *et al.*, 2024). A significantly lower score in taste observed in sample A (5.00) suggests that it may be perceived as bland or lacking complexity. Taste is a major determinant of consumer choice; thus, improving this aspect could enhance acceptability.

A favorable after-taste observed in sample D (6.52) can significantly improve the overall drinking experience, making it a key factor for consumer satisfaction. Positive

after-taste perceptions encourage repeat consumption. The low score observed in sample A (4.17) indicates that the after-taste may be perceived as undesirable, which can negatively impact consumer perceptions and lead to avoidance in future purchases.

The highest color score observed in sample D (8.38) likely indicates a vibrant, appealing hue that sugg ests freshness and quality. Color can significantly influence consumer perceptions of flavor and quality. Bright colors are often associated with fruity, flavorful drinks, enhancing overall appeal. The muted color observed in sample B (6.86) may not attract attention, potentially affecting consumer interest and purchase decisions. Color intensity can signal quality and ripeness, which are critical in food products.

The highest score in overall acceptability was observed in sample D (8.24), this suggests that it is the most preferred sample, likely due to its superior scores across sensory attributes. Consumers tend to favor products that deliver a harmonious sensory experience (Lin *et al*., 2020). While sample C (7.20) is also well-received, it doesn't quite match sample D's excellence. It indicates that while it has good sensory qualities, certain attributes, such as after-taste, could be enhanced for better acceptance.

CONCLUSION

A functional tea with acceptable sensory characteristics has been produced from underutilized plant materials some of which were regarded as waste. The physicochemical properties and color evaluation of herbal tea infusions from pawpaw leaves, pawpaw seeds, lemongrass, and negro pepper indicate that the beverage is rich in bioactive compounds and possess appealing sensory characteristics. Future research could also further explore the specific health benefits associated with these infusions and their bioactive profiles.

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