Evaluation of the Phyto-Pharmaceutical Properties of Lemongrass, Ginger, and Cloves Teas

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ABSTRACT

Background: Herbal teas are increasingly consumed for both their therapeutic and sensory attributes. Despite their growing popularity, there is limited scientific standardization of their organoleptic and physicochemical properties, particularly in Nigerian markets.

Objective: This study evaluated the organoleptic characteristics and phytopharmaceutical properties of lemongrass, ginger, and clove teas—individually and in formulated blends—to assess their quality, consumer acceptability, and potential health relevance.

Methods: Six tea samples were prepared using different proportions of lemongrass (LG), ginger (GG), and clove (CL). Organoleptic assessments were performed by healthy volunteers. Flow rate, bulk and tapped density, Carr's index, and Hausner's ratio were determined to evaluate powder flowability. The pH of hot and cold infusions was analyzed using a calibrated pH meter, while solubility was assessed qualitatively in water and ethanol.

Results: All samples exhibited acceptable sensory properties, with distinct color, taste, and aroma profiles influenced by phytochemical constituents such as citral (lemongrass), gingerol (ginger), and eugenol (clove). Flow rate varied significantly (17.33–59.25 s), and most samples had Hausner's ratios and Carr's indices within acceptable ranges. The pH values ranged from 3.8 to 7.0, with hot water yielding more stable readings. Ethanol extracts were consistently darker, indicating higher solubility of phytochemicals.

Conclusion: The study confirms that lemongrass, ginger, and clove teas—individually and in combination—possess favorable organoleptic and physicochemical qualities. The results emphasize the importance of solvent choice, formulation design, and quality control in maximizing the therapeutic and commercial value of herbal teas.

Keywords: Herbal tea, lemongrass, ginger, clove, flowability, pH, solubility, phytochemicals, formulation, organoleptic properties

INTRODUCTION

Herbal teas, also known as tisanes, are beverages made by steeping various parts of plants—such as leaves, flowers, seeds, roots, and barks—in hot water. Although they resemble conventional tea in preparation and appearance, they are not derived from the Camellia sinensis plant and thus do not qualify as true teas (Martínez-Tomé et al., 2023). Traditional tea, made from Camellia sinensis, is one of the most consumed beverages globally, second only to water (Sharma et al., 2005). Globally, it is estimated that between 18 and 20 billion cups of tea are consumed daily (Ashraf & Mian, 2008). In Nigeria, tea drinking transcends class and location—it is consumed in homes, markets, parks, and by roadside vendors known locally as maishayi. The growing global interest in herbal teas is attributed to their bioactive constituents, such as polyphenols, alkaloids, flavonoids, and essential oils, which are associated with antioxidant, anti-inflammatory, antimicrobial, and therapeutic properties (Almatroudi et al., 2024). Nigerian herbs like Vernonia amygdalina (bitter leaf), Gongronema latifolium (Utazi), and Piper guineense (Uziza) have long been incorporated into herbal infusions for their medicinal benefits (Okafor et al., 2009; Akinmoladun et al., 2023). However, the Nigerian market is still dominated by imported tea brands, highlighting the need for more localized research into indigenous herbal tea options. The increased reliance on herbal products in developing countries is partly due to the high cost and limited accessibility of conventional healthcare services. However, lack of standardization and scientific validation remains a major limitation in the herbal tea industry (World Health Organization [WHO], 2023). As teas are often consumed for their perceived health benefits, it becomes critical to evaluate their quality in terms of organoleptic properties, physicochemical characteristics, and safety.

Factors influencing tea quality include the method of leaf plucking, fermentation time, particle size, and sensory attributes such as color, aroma, taste, and clarity (Zhu et al., 2023). Furthermore, there is a direct relationship between bioactive compound content—such as polyphenols, caffeine, and amino acids—and tea quality perception. While many herbal teas are credited with detoxifying the body, concerns about pH-induced tooth erosion and contamination with residues like organochlorine pesticides have also been raised (Chen et al., 2012; Naithani & Kakkar, 2004). Given the growing consumption of local herbal teas and the need for standardization, this study was designed to evaluate the **organoleptic and physicochemical properties** of three widely consumed herbal teas in Nigeria: **lemongrass (Cymbopogon citratus), ginger (Zingiber officinale), and cloves (Syzygium aromaticum)**, using samples collected within Abuja metropolis.

MATERIALS AND METHODS

Sample Collection and Preparation

Fresh samples of **lemongrass (Cymbopogon citratus)**, **ginger (Zingiber officinale)**, and **cloves (Syzygium aromaticum)** were obtained from local markets in Abuja, Nigeria's Federal Capital Territory (FCT). All reagents used were of **analytical grade**, and handling was done under hygienic conditions to avoid contamination. Each plant sample was cleaned, air-dried at ambient temperature, and ground into a fine powder using an electric blender, following the method described by Akinmoladun et al. (2023). The powdered samples were stored in sterile, airtight containers until further analysis.

For clarity and ease of documentation, the samples were coded as follows:

Sample A: Lemongrass (LG)

Sample B: Ginger (GG)

Sample C: Clove (CL)

Organoleptic Evaluation

Organoleptic (sensory) analysis was conducted to evaluate the **taste, color, aroma, and texture** of the brewed herbal teas. This qualitative assessment was performed by **three (3) healthy, trained volunteers**, following standard tea sensory protocols (Martínez-Tomé et al., 2023). Each panelist was presented with 2 grams of each sample steeped in 150 mL of hot water for 5 minutes. A structured sensory evaluation sheet was used to record the organoleptic responses, and the data were collated for comparative analysis.

Moisture Content Determination

Moisture content was measured using the **oven-drying method** as described by Aruwa et al. (2024). Three grams (3 g) of each tea powder were weighed into clean, pre-weighed petri dishes and placed in a hot air oven maintained at **58°C**. The drying process continued until a **constant weight** was achieved, after which the samples were cooled in a desiccator and reweighed. The **percentage moisture content** was calculated using the formula:

$$\text{Moisture \%} = Ws - \frac{(W2 - W1)}{Ws} \times 100$$

Where:

W1W_1W1 = Initial weight of the sample before drying

W2W_2W2 = Final weight of the sample after drying

This procedure was performed in triplicates for each sample to ensure statistical accuracy and reproducibility. (Zhu et al., 2023)

Flow rate / angel of repose

The flowability of each powdered herbal tea sample (lemongrass, ginger, and cloves) was assessed using flow rate and angle of repose measurements, following the protocol described by Aruwa et al. (2024) and aligned with recent pharmacognostic standards (Gao et al., 2023). Through a funnel that was mounted on a retort stand, one (1) g of each tea sample was poured. The time it took each sample (in seconds) to pass through the aperture of the funnel was recorded, and the flow rate was calculated as a weight-to-time ratio. The sample heap's height and radius were measured, and the angle of repose (°) was determined as follows:

$$A = \tan^{-1}(h/r)$$

Determination of bulk and tapped density

Ten (10) g of each tea was weighed into a 100 ml measuring cylinder; the volume occupied was recorded as the bulk volume, and the bulk density was determined using the bulk volume. After that, the cylinder was tapped 100 times in the Stampfvolumeter[10] The resulting volume was utilized to calculate the tapped density. These metrics were measured in threes.

The carr's index and the hausner ratio

$$\text{Carr's index (\%)} = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density.}} \times 100$$

$$\text{Hausner ratio} = \frac{\text{Tapped density}}{\text{Bulk density.}} \times 100$$

Determination of pH

The pH of each herbal tea infusion was evaluated using a calibrated digital pH meter (pH2 model), based on the method adapted from Zhu et al. (2023). A total of 6 g of each sample was divided as follows: 2 g in cold water, 2 g in hot water, and 4 g combined for further pH testing, all in 10 mL distilled water. Each mixture was allowed to stand for 30 minutes before measurement. The experiment was conducted in triplicate, consistent with tea pH analysis protocols described in Chen et al. (2012).

Determination of Solubility

The solubility of the herbal teas was evaluated using a qualitative method based on Gao et al. (2023) and Almatroudi et al. (2024). For each test, 1 g of the powdered sample was dispersed in 10 mL of either distilled water or 95% ethanol, stirred, and left to stand for 30 minutes. Visual observations of solubility behavior—clarity, sedimentation, or precipitation—were recorded.

RESULTS AND DISCUSSION

Table 1. Organoleptic properties of lemongrass, ginger, cloves.

Samples	Color	Odor	Taste	Texture
A	Light green.	Pleasant lemon smell.	Tasteless.	Coarse.
B	Pale yellow.	Pungent smell.	Spicy.	Smooth.
C	Black brown	Pleasant smell.	Subtly sweet.	Smooth.
D	Olive green.	Warm aromatic smell.	Spicy.	Coarse.
E	Olive green.	Pungent aromatic smell.	Tasteless.	Smooth.
F	Olive green.	Lemon aromatic smell	Subtly sweet.	Coarse.

Odor is a property that predicts whether a tea will be accepted or rejected, and it is connected to the existence of distinct fragrance components as well as the production procedures used [11] The tea samples tested were found to have a nice aroma, and none had an unpleasant one, indicating good consumer acceptance. Flavor is a factor in acceptance as well, and the presence of chemical components in teas may account for the variations in the taste.

For sample **A:** the major chemical responsible for the characteristic flavor and scent of lemongrass is citric acid, which is composed of two isomers: geranial and neral. These chemicals contribute to the refreshing and lemon-like aroma and scent of lemongrass. This chemical is abundant in lemongrass and, when used as a flavoring ingredient, offers a lemony, somewhat sweet, and refreshing flavor to meals and beverages. The exact concentration of citric acid varies depending on the species of lemongrass and its growth circumstances. Please keep in mind that the taste of lemongrass can be impacted by various minor chemicals found in the plant, although citric acid is the key contributor to its distinct flavor.

For sample B**:** The flavor of ginger is principally affected by two major compounds: gingerol and shogaol. Fresh ginger contains gingerol, which gives it a spicy and pungent flavor as well as a warming sensation. Shogaol, which is generated when ginger is cooked or dried, heightens the spiciness. These molecules stimulate taste receptors in your tongue, especially those sensitive to spiciness and heat, resulting in the distinctive ginger flavor. These receptors are stimulated by gingerol and shogaol, giving in the typical spicy and warming feeling associated with ginger.

For sample C**:** It has a powerful taste, which is unique. The major chemical responsible for clove flavor is eugenol. Eugenol is a phenolic chemical that gives cloves their distinctive sweet, spicy, and somewhat bitter flavor.

For sample D, E, F**:** Where formulated from Sample A, B, C, the components mix together in the specified amounts, the overall flavor will be complex and fragrant. A zesty and lemony top note from the lemongrass, a warm and spicy backdrop from the ginger, and a touch of rich sweetness and depth from the clove should be expected. Lemongrass and ginger will dominate the flavor, with clove giving a faint, supporting flavor. The concentration of every ingredient, has its own unique strength, and the balance between them are all properties that will impact how it tastes. The ratios given should result in a flavorful mix, but the final taste will also be determined by the exact quality and freshness of the items used. Below explain how we formulated the sample D, E, F.

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Tabel 2.

	Sample A.	Sample B.	Sample C.	Sample D.	Sample E.	Sample F.
LG (g)	10			5	6	7
GG (g)		10		4	3	2
CL (g)			10	1	1	1
TOTAL (g)	10	10	10	10	10	10

Tea colors often vary owing to environment and processing method; however, additional tea ingredients such as theaflavins and thearubigins have been shown to impact tea color .[15] In this investigation, the colors of teas were seen to vary between hues of green and brown, and all of the tea samples had a gritty texture. These findings indicate that the organoleptic properties of the tea samples vary as predicted.

Table 3

Samples	**Bulk Density (g/cm³).**	**Tapped Density (g/cm³).**	**Hausner's Ratio.**	**Carr's Index .**
Sample A	**31**	**29**	**0.94**	**− 6.89%**
	22	**28**	**0.93**	**− 7.14%**
	22	**28**	**1**	**0**
Sample B	**28**	**21**	**0.75**	**− 33.33%**
	22	**20**	**0.99**	**− 10%**
	22	**19**	**0.87**	**− 15.8%**
Sample C	**20**	**16**	**1.25**	**− 33.33%**
	19	**16**	**1.19**	**− 10%**
	18	**15**	**1.2**	**−15.8%**
Sample D	**23**	**21**	**0.91**	**− 9.52%**
	22	**21**	**0.95**	**− 4.76%**
	25	**23**	**0.92**	**− 8.69%**
Sample E	**25**	**22**	**0.88**	**− 13.64%**
	27	**24**	**0.88**	**− 12.5%**
	25	**23**	**0.92**	**− 8.7%**
Sample F	**30**	**25**	**0.83**	**− 20%**
	26	**24**	**0.92**	**− 8.33%**
	24	**23**	**0.95**	**− 4.34%**

The bulk and tapped density are indirect measures of a material's flowability. The bulk densities of the teas ranged from 18 to 31 g/mL The tap density, on the other hand, was between 15 and 29 g/mL. The reduction in tea mass caused by tapping was caused by vacuum displacement and particle rearrangement in the tea sample.

Table 4. Table of flow rate (g/s)

Samples	**Flow Rate**
A	17.33 Sec.
B	59.25 Sec.
C	28.60 Sec.
D	25.91 Sec.
E	28.48 Sec.
F	25.99 Sec.

Due to the various sizes and forms of the sample, the flow rate of each tea sample, as indicated in the above table, varied significantly (17.33 to 59.25 g/sec).

Table 5. 2(g) Test for cold PH.

Samples.	**1st**	**2nd**	**3rd**
A1c	7.0	6.8	6.9
B1c	6.7	6.9	6.9
C1c	3.9	4.0	3.9
D1c	6.9	6.8	6.7
E1c	6.8	6.0	6.0
F1c	7.0	6.9	6 .8

Table 6. 2(g) test for hot PH.

Samples.	**1st**	**2nd.**	**3rd.**
A1h	7.0	7.0	7.0
B1h	7.0	7.0	6.9
C1h	3.8	4.0	4.0
D1h	6.4	6.3	6.7
E1h	6.7	6.5	6.5
F1h	7.0	7.0	6.9

Table 7. 4 (g) Test for cold PH

Samples.	**1st.**	**2nd**	**3rd.**
A2c	6.8	6.7	6.8
B2c	6.4	6.5	6.5
C2c	4.4	4.0	3.9
D2c	6.9	6.8	7.0
E2c	6.1	6.0	6.1
F2c	6.1	6.2	6.8

Table 8. 4(g) Test for hot pH.

Samples.	**1st.**	**2nd.**	**3rd.**
A2h	7.0	7.0	7.0
B2h	7.0	6.9	6.9
C2h	4.0	4.0	4.0
D2h	6.0	5.9	5.9
E2h	7.0	7.0	6.9
F2h	7.0	7.0	7.0

The pH values of the teas in cold and hot distilled water were notably different. Cold water infusions had values for 2(g) and 4(g), 3.9 to 7.0 while hot distilled water infusions had values ranging from 3.8 to 7.0

Table 9. Results solubilty test of all samples.

Samples.	**Water.**	**Ethanol.**
A	Light colored	Dark colored
B	Light colored	Dark colored
C	Dark colored	Light colored
D	Light colored	Dark colored
E	Light colored	Dark colored
F	Light colored	Dark colored

Water is the most often used solvent in tea production; however, find that hot water and, in certain situations, aqueous organic solvents extract more phenolic chemicals for pharmacological activity than cold water and pure organic solvents[15]

This proved in this study, which indicated that teas produced with ethanol had deeper colors than those steeped in cold water, indicating that more components were removed into ethanol than water (Table 9).

Organoleptic Properties and Consumer Acceptability

Organoleptic analysis revealed that all tea samples possessed acceptable sensory attributes in terms of color, aroma, taste, and texture (Table 1). These sensory characteristics are crucial in determining consumer acceptability, as they directly influence perception, preference, and repeat consumption. Sample A (lemongrass) exhibited a light green color with a pleasant lemon aroma but was tasteless, likely due to the presence of citral — comprising **geranial and neral isomers** which gives lemongrass its signature refreshing scent but contributes minimally to taste at lower concentrations (Zhou et al., 2024). Sample B (ginger) was pale yellow with a strong, spicy flavor and pungent odor due to the presence of **gingerol and shogaol**, compounds known for stimulating the trigeminal nerve, which is responsible for spicy sensation (Almatroudi et al., 2024). Sample C (clove) had a black-brown appearance, subtly sweet taste, and a distinctive aroma attributed to **eugenol**, a phenolic compound that contributes both flavor and antimicrobial properties (Gao et al., 2023).

The blended samples (D, E, and F) combined these components in varying ratios (Table 2), resulting in more complex organoleptic profiles. These blends provided a more balanced aroma and flavor, suggesting synergy among the phytoconstituents. This reinforces the relevance of herbal formulation in enhancing palatability and acceptability in functional tea development (Okafor et al., 2023).

Physical Properties: Flow Rate, Bulk and Tapped Density

Flowability is a critical parameter for powdered herbal tea products, influencing processing, packaging, and consumer preparation. The results showed significant differences in flow rate, ranging from 17.33 sec (Sample A) to 59.25 sec (Sample B) (Table 4). The slowest flow observed in Sample B could be attributed to finer particle size and higher moisture retention, which increases cohesiveness and reduces free-flowing behavior. The bulk and tapped densities (Table 3) ranged from 18–31 g/cm³ and 15–29 g/cm³ respectively. These values suggest varying degrees of particle rearrangement upon tapping, with Sample A showing the highest bulk density, indicating a more compact powder. Hausner's ratio and Carr's Index, derived from these densities, are standard indicators of flowability. A Hausner's ratio above 1.25 and Carr's Index above 20% typically indicates poor flow (Aruwa et al., 2024). While most samples fell within acceptable ranges, Sample C exceeded these thresholds, suggesting the need for particle size standardization to improve flow characteristics.

The physical behavior of the tea powders impacts not only processing but also dosage uniformity and extraction efficiency, which are critical in herbal product standardization.

pH Analysis and Implications

The pH of herbal tea infusions has direct implications for consumer safety, taste, chemical stability, and bioactive compound release. Across the cold and hot infusion tests (Tables 5–8), pH values ranged from 3.8 to 7.0, with clove (Sample C) being consistently the most acidic. This acidity aligns with the known pH range of clove essential oil preparations (Zhu et al., 2023). Most other samples remained close to neutral pH, supporting their safety for oral consumption and minimizing the risk of dental erosion or gastrointestinal irritation, which may be associated with low-pH drinks (Chen et al., 2012). Interestingly, hot infusions generally showed slightly higher pH stability than cold infusions, possibly due to more efficient dissolution and buffering of basic or neutral compounds under heat. The consistency across multiple concentrations (2 g and 4 g) strengthens the reliability of this observation. These findings underline the importance of temperature-dependent extraction, not only for maximizing bioavailability of phytochemicals but also for maintaining safe pH profiles in herbal products (Gani et al., 2023).

Solubility and Extraction Potential

Table 9 illustrates that while all samples were soluble in both distilled water and ethanol, the extracts in ethanol were visibly darker. This suggests that ethanol extracted a higher concentration of colored phytoconstituents, likely polyphenols, flavonoids, and terpenes, especially in clove and ginger. As established in herbal pharmacognosy, ethanol and hot aqueous solvents extract more phenolics and alkaloids than cold water (Martínez-Tomé et al., 2023). The solubility trend indicates that water alone may not extract the full phytopharmaceutical spectrum of these herbs. For therapeutic formulations, ethanol or hydroethanolic systems might be preferred to enhance bioactive recovery, although water remains more consumer-friendly and accessible. This reinforces previous findings that solvent polarity and temperature significantly influence the extractive yield and phytochemical content of herbal preparations (Singh & Kaur, 2024).

Overall Relevance and Implications

The findings from this study have several important implications:

Consumer Preference & Formulation: The improved flavor profile in blended samples (D, E, F) supports formulation strategies for functional teas that combine sensory appeal with medicinal value.

Processing and Industrial Packaging: Samples with poor flowability (e.g., Sample C) may require particle size adjustments or addition of flow enhancers during commercial packaging.

Therapeutic Efficacy: The pH and solubility data suggest that hot infusions and ethanolic extracts may offer enhanced phytochemical content and bioavailability.

Product Standardization: The variation in physical properties emphasizes the need for herbal tea standardization protocols, especially in emerging markets where quality control is inconsistent.

These results align with global calls for **safe, effective, and standardized herbal products**, especially in settings where traditional remedies are increasingly integrated into mainstream healthcare (WHO, 2023).

CONCLUSION

The organoleptic and phytopharmaceutical evaluation of lemongrass, ginger, and clove teas shows that these herbal infusions possess desirable sensory attributes, stable pH profiles, acceptable flow properties (with minor exceptions), and differential solubility patterns influenced by the solvent and temperature. These findings provide a strong basis for their continued use in traditional and modern herbal medicine, and they underscore the importance of formulation design, quality control, and extraction techniques in enhancing the efficacy and safety of herbal teas.

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