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Original Research Article

Sensory and Phytochemical Evaluation of Infusions from Lemongrass (*Cymbopogon citratus*) Compared with Four Teas Used in Morocco

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ABSTRACT

The aromatic, flavorful, and fragrant qualities of lemongrass (*Cymbopogon citratus*) make it a valuable herb for culinary and medical uses. This study investigated the sensory quality of *C. citratus* and its richness in chemical compounds. The sensory tests were realized on the infusion of the plant and compared to 4 Teas among a group of participants. Further, total polyphenol, flavonoid, and tannin contents, and antioxidant activity were evaluated in the infusions of tested products. The primary metabolites in the dry matter of the plant were also measured. Before beginning, each participant was required to read and fill out an informed permission form by the national legislation and the Declaration of Helsinki's Ethical Principles for Medical Research Involving Human Subjects. Participants were aged between 20 and 60 years old with dominance of 20-39 years old (80%). Moreover, 60% of participants were women compared to 40% of men. Half the participants drink aromatized tea, mainly menthe. The infusion of *C. citratus* had the highest rating, calculated at 9.33±0.62 compared to the other aromas. The infusion of *C. citratus* was distinguished by its strong flavour and order, as well as its pleasant aroma, flavor, and aftertaste. The values of TPC, TFC, and tannin were 0.463 mg eq Q/g dry matter, 0.033 mg eq Q/g dry matter, and 21.96 mg eq AT /g dry matter, respectively. The antioxidant activity was 98.07%. The total sugar was the most dominant in the infusion of the plant with 0.376 g per g of dry matter of *C. citratus*, followed by lipids with 0.106 g per g of dry matter. This study presents new data on the nutritional value of *C. citratus* in Morocco and is suggested to be a reference for future research.

***Keywords*:** *Cymbopogon citratus*, infusion, nutritional quality, chemical content, antioxidant activity.

Introduction

Lemongrass *Cymbopogon citratus* (DC.) Stapf is a species of tropical herbaceous plant in the family Poaceae[1,2]. The botanical nomenclature assigned to lemongrass is *Cymbopogon citratus*, which originates from the Greek terms "kymbe" (denoting a boat) and "pogon" (indicating a beard). This nomenclature specifically alludes to the structural configuration of the flower's spike[3]. *Cymbopogon citratus* is a perennial tropical grass that grows in different climates semi-warm, warm, and temperate [4,5]. The herb under consideration is a perennial grass that is Indigenous to and widely dispersed over the continents of North and South America, Africa, and Asia[6]. The plant can reach 1.20 m in height and the leaves exhibit a green coloration, elongated shape, and possess a distinctive fragrance and flavor[1,7]. Therefore the plant is used in food and medicine[8–10].

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Cymbopogon citratus is nutritionally considered a valuable source of essential vitamins such as A and C, and folic acid, as well as important minerals like zinc, magnesium, iron, copper, calcium, potassium, and manganese.[11] *Cymbopogon citratus* leaves have long been used as a culinary ingredient, and they are frequently included in a variety of cuisines, especially curries[9]. The leaves of the plant in Africa, South America, and Asia continents have historically been utilized for the preparation of decoctions or tea[12].

The therapeutic goods of *C. citratus* have been well-documented in conventional and updated medicine[13,14]. Previous scientific studies have documented the many biological activities shown by *C. citratus*, including its, antioxidant, antiprotozoal, antibacterial, cardio-protective, antifungal, anti-carcinogenic, anti-rheumatic, and anti-inflammatory effects[15,16]. Additionally, it has been documented to have inhibitory effects on platelet aggregation and demonstrated potential therapeutic efficacy in the treatment of gastrointestinal infections, diabetes, pneumonia, malaria, depression, and anxiety[15,16]. The plant's leaf possesses vital bioactive compounds that give it numerous medicinal advantages, such as anti-inflammatory, anti-dyspeptic, anti-fever, and antiseptic properties. Furthermore, it exhibits analgesic, anti-hermetic, antispasmodic, antipyretic, diuretic, and tranquilizing characteristics[17].

The presence of secondary metabolites or phytochemicals may be responsible for the medicinal plants' ability to treat illnesses[18–21]. These chemicals are uniformly distributed among medicinal plants. Various significant compounds, including flavonoids, amino acids, anthocyanin, phenolic composites, volatile constituents, phytosterols, valeric esters, fatty acids, isopulegol, p-coumaric acid, methylheptenone, fumesol, organic acid, isovaleric aldehyde, L-

linanool, furfurol, and have been successfully extracted and identified from *C. citratus*[15,22]. However, these chemicals vary depending on various factors including extracted part of the plant, used extraction solvents, and the environmental conditions[23–25]. The leaf of *Cymbopogon citratus* has a significant concentration of essential oil[8,26,27]. It contains α-oxo bisabolene citronellol (Cymbopogone and Cymbopogonol), geraniol, myrcene, and citral (mixture of geranial and terpernoids) [26,27]. The composition of these substances exhibits variation under the effect of plant material (species and their genetics) and the geographical region of the growth. Equally, the extracts of *C. citratus* showed significant quantities of total polyphenols and content of flavonoids, as well as antioxidant activities[28,29]. However, these compounds vary depending on the extraction solvents[29]. Therefore, more investigations are needed to characterize the most productive extraction solvents and methods to obtain the maximum quantity of bioactive compounds from *C. citratus*. These are proposed to optimize the biological activities of the plant, and then its use in pharmacy and industry fields.

This study aimed to investigate the nutritional value of infusion from leaves of *Cymbopogon citratus* in comparison with infusions of four types of tea used by the Moroccan population, including Sebaa 4011, tea Dahmiss 41022, tea Rahal 9371, and tea Kafila. Equally, we evaluated the chemical properties of these infusions including antioxidant activity, total flavonoids, polyphenols, and tannins. Next, we examined the dry matter components found in *Cymbopogon citratus* leaves. These parameters are suggested to demonstrate the food quality of *Cymbopogon citratus* and the principal role of chemicals in it.

Methods and Materials

Cultivation of plant

To realize this study, the cultivation plot was prepared in the botanic garden of the Faculty of Sciences and Technologies, Sidi Mohamed Ben Abdellah University in Fez (Central Morocco). the dimensions of the garden were estimated at 25 m (width) x 40 m (length) with a total area of 1000 m2. Further, a limited space of 6 m x 4.5 m was destined for the greenhouse, where students prepare their cultures. In terms of vegetation, the garden is rich in medicinal and agronomic plants such as *Rosmarinus* sp, *Mentha* sp, *Lavandula* sp, *Olea europaea*, *Persea americana, and Mespilus germanica*.

In this case, we prepared a small plot with dimensions of 3 m (width) and 5 m (length) (Figure 1). Then, we planted the rhizomes of *Cymbopogon citratus*, brought from the National Agency of Medicinal and Aromatic Plants located in Taounate province (east of Fez, Morocco). The planted rhizomes were irrigated regularly during each 3 days with gravity irrigation (Figure 1A and B). After 32 days, the planted fragments showed their new leaves as presented in Figures 1 A and B. Further, the maturity of the plant was after 120 days (Figure 1 E and F). The height of the plant reached 180 cm, and the leaves are 98 cm long and 1 cm wide. Then we collected the samples for laboratory research. During the entire study period, chemical fertilizers for pest control were not applied.

Figure 1: Preparation of plot and cultivation of *Cymbopogon citratus* (A and B), appearance of leaves (C and D), and maturity of planted plants in the garden of Faculty of Sciences and Technology of Fez (34° 03′ 00″ north, 4° 58′ 59″ west)

Plant material

In this study, the vegetal material was *Cymbopogon citratus.* This plant was offered by the National Agency of Medicinal and Aromatic Plants in Taounate. Further, leaves of the plant were gathered from the Faculty of Sciences and Technologies (FST) Botanical Garden in Fez (34° 03′ 00″ north, 4° 58′ 59″ west). The harvest was carried out when the plant reached a height of approximately 60 to 110 centimeters. The leaves were utilized in the process of extracting essential oils. First, the leaves were left to dry at room temperature and in the open air on boards until all moisture was lost. After that, the leaves were ground

into a fine powder using an electric grinder, which was utilized for the different extraction processes.

Extraction and dosage of phenolic compounds

The extraction was realized following the extraction procedure depicted by Li *et al.* [30] . Further, 30 g of dried powdered leaves were put in 200 ml of methanol with stirring; this operation was repeated three successive times, for 2 hours, with renewal of the solvent each time. After filtration, the remains were placed in a rotavapor (Buchi R-300, Germany) at a temperature of 40°C; at the end, a crude extract was obtained. The latter was stored in clean, sterile, and tightly closed glass vials.

The reagent used was the Folin-Ciocalteu reagent; it was a mixture of yellow-colored phosphotungsten ($H_3PW_{12}O_{40}$) and phosphomolybdenum ($H_3PMO_{12}O_{40}$) acid complexes. Total phenolic compounds were measured as follows: A volume of 1 mL of Folin reagent, which had been diluted by a factor of 10, was introduced into a 200 µl sample that had been appropriately diluted. Following a duration of 4 minutes, an 800 µl volume of a sodium carbonate solution with a concentration of 75 g/l was introduced into the reaction medium[31]. After 30 minutes, the phenolic content was estimated at 765nm with a spectrophotometer (Infitek SP-IUV7 France). The determination of total polyphenol content was derived using the regression equation obtained from the calibration range constructed using gallic acid (with concentrations of 0-1000 μg/ml). Moreover, the concentration was then represented as micrograms (mg) of gallic acid equivalent (EAG) per milligram of dry matter (mg EAG/g DM).

Dosage of flavonoids

The trichloride of aluminum ($AlCl_3$: Merck) approach was used to quantify the flavonoids in the extract[32]. The principle is based on the oxidation of flavonoids by this reagent (AlCl3), which leads to the formation of a yellow-orange complex that absorbs at 420 m. The yellow-orange colour produced was relative to the quantity of flavonoids existing in the tested extract[33]. For the dosage, extract (1 ml) was placed in a test tube containing 2% methanolic aluminum chloride (1 ml) solution. Further, following 60 minutes of incubation period at ambient temperature, the absorbance of the prepared combination was realized at 420 nm wavelength utilizing a spectrophotometer. Furthermore, the estimation of flavonoid concentration was realized by utilizing a calibration range consisting of various quantities (concentrations) of quercetin (0-1 g/l). The results were expressed as the equivalent of milligrams of quercetin per gram of dry matter.

Anti-radical activity (DPPH test)

The DPPH assay is extensively employed as a technique for investigating antioxidant activity in various research studies. DPPH, also known as 2,2-diphenyl-1-picrylhydrazyl, is distinguished by its capacity to generate enduring free radicals. The solution has a dark purple hue due to the presence of DPPH radicals, which exhibit absorption at around 517 nm. The darkening of the solution occurs because the antioxidant agent reduces DPPH radicals. In this study, a volume of 1950 µl of a methanolic solution containing DPPH (Sigma–Aldrich) at a concentration of 10-5M was introduced to 50 µl of each extract at several concentrations ranging from 1 to 6 mg/ml. Moreover, a negative control was created by mixing 1950 µl of DPPH with 50 µl of methanol. The positive control consisted of varying quantities (0.01, 0.02, 0.04, 0.06, 0.08, 0.1 mg/ml) of ascorbic acid. Following a 30-minute incubation period at ambient temperature, the absorbance of the prepared tubes was determined at 515 nm wavelength. The formula (A) provided by Yen et al. (1994) calculates the % decrease in DPPH.

A) $\%\, of\ DPPH\ = [\frac{(OD\ at\ t0)-(OD\ at\ t30min)}{OD\ at\ t0}\ \times\ 100]$

The % of DPPH: percentage of reduction or inhibition of DPPH. Optical density (DO) at t0: optical density of DPPH at t0. OD at t30: optical density at 30 min after adding the extract.

Extraction and Dosage of Total Sugars

The extraction and quantification of sugars were realized following the protocol adapted from [34]. In our case, 200 mg of *Cymbopogon citratus* powder was macerated in 10 ml of distilled water for 1 hour. Additionally, the mixture of total sugars contained in the supernatant was recovered and tested. The assay was done using the phenol/sulfuric acid method; 200 μl of the prepared dilutions from the supernatant were added to 1000 μl of 96% concentrated sulfuric acid. Following the homogenization process, the resulting mixture was subjected to a water bath at a warmth of 100°C for a period of 5 minutes, after which it was then kept in a dark environment for a period of 30 minutes. The absorbance measurements were conducted at 480 nm wavelength. The quantification of total sugars was evaluated by reference to a calibration curve carried out with diverse glucose concentrations.

Determination of reducing sugars

The quantification of decreasing sugar concentration was conducted using the methodology outlined by Miller, [35] applying 3-5-dinitro-salicylic acid (DNS: LOBA CHEMIE). The reduction sugars were measured by placing 1 ml of DNS and 1 ml of the prepared supernatant in an experiment tube. The obtained combination was then homogenized and brought to a bath of boiling water for 20 min. Further, 4 ml of distilled water was inserted into the medium during cooling. The reading of the optical density with the spectrophotometer was carried out at 540 nm.

Protein extraction and dosage

Protein extraction and dosing were performed by Bradford's procedure[36]. In this case, it was necessary to homogenize 100 mg of powder in a 10 ml phosphate buffer solution. After that, the homogenate was centrifuged for 45 minutes at 500 mg, and the prepared supernatant was collected. Further, 1000 μl of various dilutions from the supernatant were combined with 5 ml of Bradford reagent, following a period of incubation lasting 5 minutes under conditions of darkness, the optical density (absorbance) was evaluated at 595 nm. Further, a standard range was produced with increasing quantities of bovine serum albumin (BSA: Sigma–Aldrich): 0.0.02, 0.04, 0.06, 0.08, 0.1 g/l. The samples and the blank were accommodated to a final volume of 1000 µl, the absorbance was evaluated at 595 nm against a blank.

Dosage of citric acid

Citric acid was also evaluated in this study. In this instance, 40 ml of distilled water and 2 g of lemongrass powder were combined and centrifuged. Further, 20 ml of supernatant (after centrifugation with Nuve NF 200 turkey) was collected and a few drops of phenolphthalein were added. Eventually, the NaOH was used for titration.

Sensory evaluation

To realize the sensory evaluation the method described by Bakota et al was followed[37]. In this case, five products were prepared: tea Sebaa 4011 (T1); tea Dahmiss 41022 (T2); tea Rahal 9371 (T3); Lemongrass infusion (T4); and tea Kafila (T5) (Figure 2). In this experiment, one litter of water was used. Further, 80g of sugar and 15g of each product were added to the water. Then, the infusion was versed in cups characterized by the name of each product.

The products were prepared on panels and presented to participants. The sensory experiments were performed in the Faculty of Sciences and Technology of Fez. The students tested the products and evaluated their preference toward them, while the quality was from 1-10. The selection of students was random, and the total number of participants was 20.

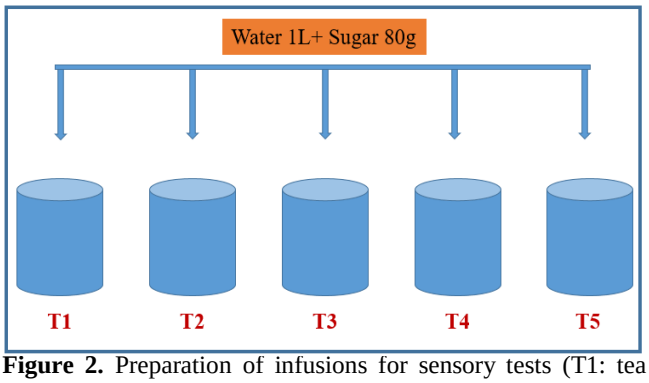

Figure 2. Preparation of infusions for sensory tests (T1: tea Sebaa 4011; T2: tea Dahmiss 41022; T3: tea Rahal 9371; T4: Lemongrass infusion; and T5: tea Kafila).

Ethics considerations

The survey's initial page provided a clear explanation of the study's goals as well as the researchers' contact information. Before beginning, each participant was required to read and fill out an informed permission form by the national legislation and the Declaration of Helsinki's Ethical Principles for Medical Research Involving Human Subjects. No personally identifying data was gathered.

Statistical analysis

The data was gathered, organized in Excel, and checked for normalcy (three replicates for each parameter). The means of studied parameters in the *C. citratus* aqueous, ethanol, and methanol extracts were compared using the ANOVA One-way test. The sensory evaluation of the evaluated samples was compared using the Multiple Range test. The findings were displayed as mean±SD, with a significance at $p \leq 0.05$. Principal Component Analysis was used to analysed the sensory parameters. All statistical analyses were conducted using IBM SPSS 25.

Results and Discussions

Sensory evaluation and taste tests

Demography of participants

Demographic characteristics (age and gender) of participants in sensory tests are presented in Figure 3. The participants in sensory experiments were aged between 20 and 60 years old. Further, most participants (80%) were aged between 20 and 39 years old, while the minority (20%) were aged between 40 and 60 years old. Moreover, 60% of participants were women, while men presented only 40% of participants. Figure 4 displays the findings from the individuals' sensory backgrounds. Every single participant (100%) has tea in their houses. In a similar vein, every individual reported having prior sensory experiences. The tea that each participant used was different. Moreover, half the participants drink aromatized tea, and the other half drink non-aromatized tea. Of the participants, 50% utilized menthe in their tea, and 33.33% used verbena as the tea's scent. The least popular tea aroma among participants was thyme (16.66%).

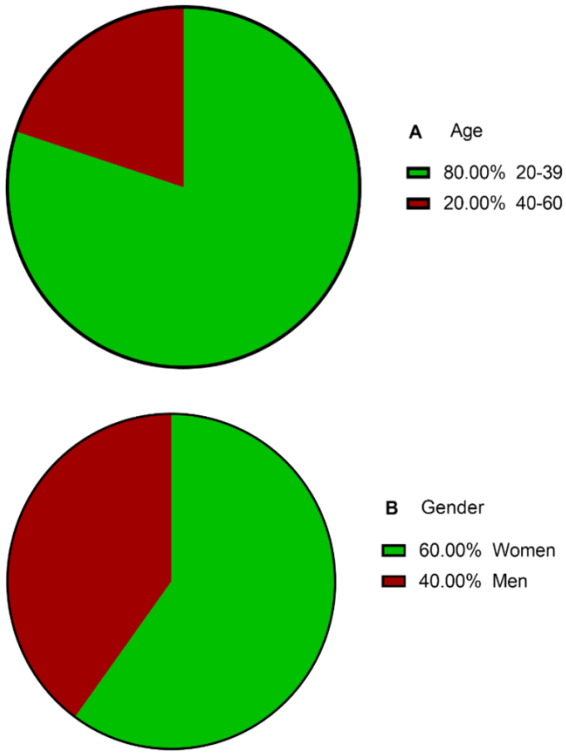

Figure 3. Demographic characteristics (A: age and B: gender) of participants in sensory test

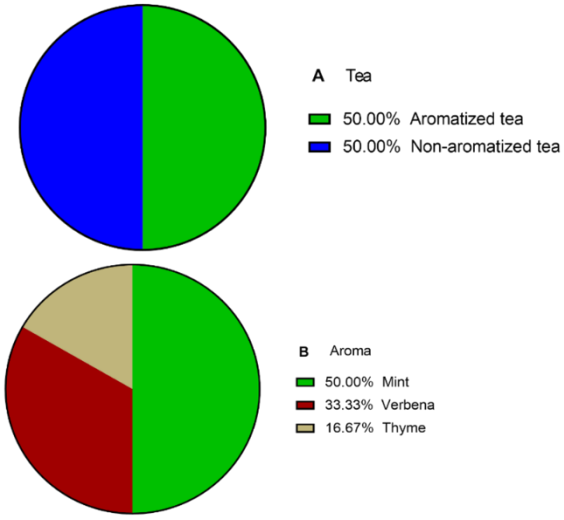

Figure 4. Sensory background of participants concerning tea (A) and aroma (B)

Taste tests

Figure 5 presents the findings from the sensory tests. The multiple-range test revealed a noteworthy variation between the goods that were examined. Out of all the products that were evaluated, the infusion of *Cymbopogon citratus* had the highest rating, calculated at 9.33±0.62. The mark showed statistical similarity with T1 (5.25±0.23), T2 (4.8±0.12), T3 (5.88±0.21), and T5 (4.7±0.16) among other products. Figure 6 displays the flavor parameters' Principal Component Analysis results. Two axes make up the plot of taste parameters; the first component shows 75.89% of the data, while the second component shows 16.54%. The infusion of *Cymbopogon citratus* was distinguished by its strong flavour and order, as well as its pleasant aroma, flavour, and aftertaste. Moreover, the only difference between

T1, T2, and T3 products was their increased bitterness. Moreover, T5 on the other hand, exhibited greater classification and astringency. However, there was no difference in the examined products' brilliance, colour, or clarity criteria.

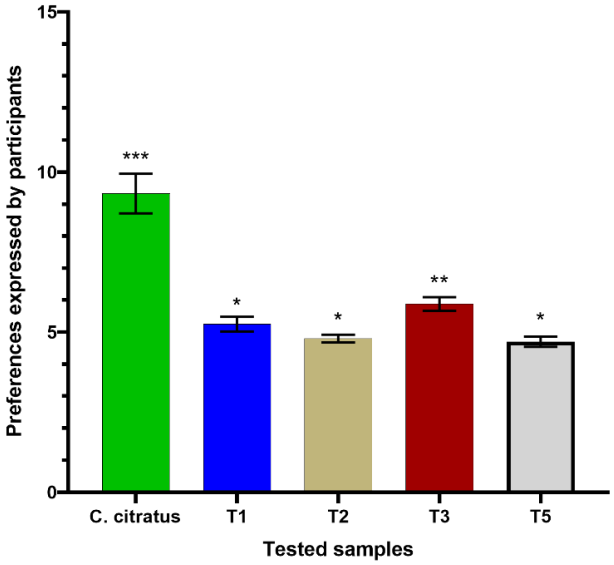

Figure 5. Comparison of taste parameters between tested samples based on responses of participants (***>**>* denote statistically different at p≤0.05)

This study tested for the first time the nutritional quality of *Cymbopogon citratus*. It tested the taste of infusion from *Cymbopogon citratus*, with tea Sebaa 4011, tea Dahmiss 41022, tea Rahal 9371, and tea Kafila. *Cymbopogon citratus* is a medicinal plant known for its diverse chemical compounds, which contribute to its biological and forage properties[11,22,38,39]. Mascarin *et al.* [40] evaluated the sensory of fermented orange beverages containing increasing aromatic herbal extracts from *Cymbopogon citratus*, *Mentha piperita*, and *Matricaria recutita*. The results showed that all fermented orange beverages containing herbal extracts had similar tastes and sensory parameters (color, taste, and aroma) were significantly important. In another study, Alagendran *et al.* [38] measured the sensory quality of the leaves from the lemongrass (*C. citratus*). The efficacy of Lemongrass leaf powder was evaluated by the authors in a controlled experiment with a sample size of 50 individuals who were specifically chosen for their expertise in the subject matter. These panelists were then given explicit instructions to rate their level of acceptance for six distinct aspects of the infusions, namely color, scent, flavor, aftertaste, astringency, and overall acceptability. A substantial proportion, over 75%, of the examined samples of Lemongrass green tea exhibited teeth incises, albeit with little strength. Similarly, around thirty percent of the samples of Lemongrass green tea exhibited an overall sensory profile encompassing scent, color, taste, and sweetness, which was evaluated using a hedonic scale. The initial rating of this sensory profile was 7.25, which subsequently increased to 8.00 on the first day. The results of our study are directly related to the chemical compounds recorded in the leaves of the *Cymbopogon citratus*.

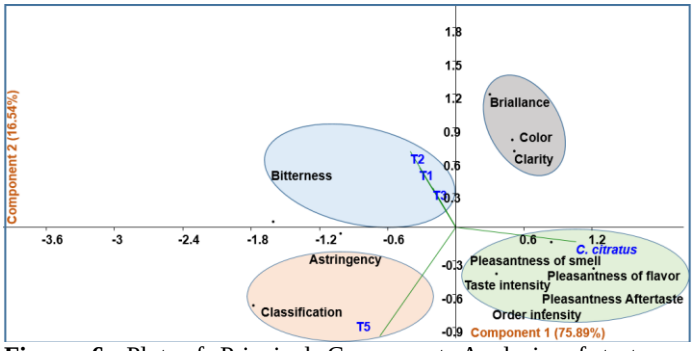

Figure 6. Plot of Principal Component Analysis of taste parameters among participants

Chemical composition and nutritional value

Total polyphenols, Flavonoids and Tannins

The dosage of total polyphenol content in the infusion of tested samples is presented in Figure 7A. The infusion of evaluated products showed variable quantities of total polyphenol compounds. The highest value of total polyphenol content was recorded in T2 (0.565 mg eq Q/g dry matter), followed by T1 (0.545 mg eq Q/g dry matter) and T3 (0.543 mg eq Q/g dry matter). The lowest values of total polyphenol content were recorded in T5 (0.494 mg eq Q/g dry matter) and T4 (0.463 mg eq Q/g dry matter). The dosage of total flavonoid content in the infusion of tested samples is presented in Figure 7A. The infusion of evaluated products showed variable quantities of total flavonoid compounds. The highest value of total flavonoid content was recorded in T3 (0.318 mg eq Q/g dry matter), followed by T2 (0.243 mg eq Q/g dry matter) and T1 (0.181 mg eq Q/g dry matter). The lowest values of total flavonoid content were recorded in T5 (0.111 mg eq Q/g dry matter) and T4 (0.033 mg eq Q/g dry matter). The dosage of tannin contents in the infusion of tested samples is presented in Figure 7B. The infusion of evaluated products showed variable quantities of tannin compounds. The highest value of tannins was recorded in T2 (87.23 mg eq AT /g dry matter), followed by T1 (64.81 mg eq AT /g dry matter) and T3 (62.33 mg eq AT /g dry matter). The lowest values of total flavonoid content were recorded in T5 (mg eq AT /g MS) and T4 (21.96 mg eq AT /g dry matter).

This study investigated the chemicals in infusion from leaves of *Cymbopogon citratus* and recorded results demonstrating variable quantities of tannins, total flavonoids, and polyphenols, compared to the tested teas. Costa *et al.*[41] investigated the tannins, flavonoid, and polyphenol contents and antioxidant properties in the infusion of *C. citratus* infusion under the effect of the harvest period and quality of the material. The total phenol contents exhibit notable stability during the months of July (5.35%), June (5.55%), and April (5.67%). However, a statistically pointed rise was observed in samples of August (6.14%), pursued by a subsequent decline to the lowest values in samples harvested during September (4.58%). Moreover, the phenolic compounds known as total flavonoids exhibited a statistically significant decline during the harvest date of August (4.81%). The highest concentrations of total flavonoids were seen in the months of June (6.63%) and September (6.62%). The concentration of tannins exhibited an upward trend from April (2.89%) to August (3.96%), thereafter declining to its lowest point in September (2.97%). In another study [42], evaluated the effect of harvesting features on sensory traits and phenolic constituents in infusions from leaves of *C. citratus*. According to the study's findings, the phenolic content of the tips of leaves cut by hand ranged from 23.07 ± 0.028 mg GAE g^{-1} dry leaf to 16.09 ± 1.62 mg GAE g^{-1} dry leaf for the second half of the leaves cut by hand. In another study, Gião *et al.* (2007) noted a total phenolic compound of 66 mg GAE/L. Equally, other studies have addressed the total polyphenols in extracts of this plant. Unuigbe *et al.* [43] investigated the total contents of flavonoids and polyphenols in extracts from leaves of *Cymbopogon citratus*. These authors used different extracts including ethyl acetate (500 mL), n-hexane (600 mL), and chloroform (600 mL). Results showed that the fraction of ethyl acetate had the greatest TPC (172.50 mg GAE/g of extract), followed by the chloroform (160.00 mg GAE/g of extract), extract of

methanol (132.50 mg GAE/g of extract), and fraction of n-hexane (104.00 mg GAE/g of extract). Further, the total flavonoid compounds were high in the ethyl acetate (192.60 mg QE/g of extract), followed by the extract of chloroform (153.00 mg QE/g of extract), crude extract of methanol (143.00 mg QE/g of extract), and fraction of n-hexane (80.20 mg QE/g of extract). In another study[44], evaluated the total polyphenols and flavonoids in hexane and methanol leave extracts of *Cymbopogon citratus*. The results demonstrated that the value of total phenolic contents in hexane extract was 72.55 ± 0.29 mg/kg, while in methanol extract the value was 66.94 ± 0.14 mg/kg. The total flavonoid content of hexane (HE) and methanol (ME) was 3.53 ± 0.05 mg/kg and 3.35 ± 0.05 mg/kg, correspondingly. These results are in agreement with our results and confirm the variability of TPC and TFC in extracts depending on the used solvent. Antioxidant activity is described "as a limitation of the oxidation of proteins, lipids, DNA or other molecules that occurs by blocking the propagation stage in oxidative chain reactions" and fundamental antioxidants rummage free radicals.

Antioxidant activity

The calculation of antioxidant activity among infusions of tested products is presented in Figure 7C. The obtained results showed that the percentages of inhibition are statistically similar among tested samples. The value of inhibition percentage was estimated at 99.21% in T1, 99.03% in T5, and 98.86% in T3. Further, the inhibition percentages were 98.77% in T2 and 98.07% in T4.

This study evaluated the antioxidant activity in the extracts from leaves of *Cymbopogon citratus* and obtained results that showed a significant variation in DPPH scavenging activity depending on the used solvent. The methanolic extract has better anti-radical activity than water and ethanol. Currently [45], showed a significant difference in Antioxidant Activity between ethanol and acetone extracts from leaves of *Cymbopogon citratus*. Scavenging activity was 73.8 ± 0.9) in ethanol and 67.9 ± 0.7 in acetone extract. In another study [43], compared the antioxidant activity among different extracts from the leaves of *Cymbopogon citratus*. The ethyl acetate fraction exhibited the highest activity (IC50 = 4.53 ± 0.71 μg/mL), followed by the chloroform (IC50 5.3 ± 1.01 μg/mL), the methanol (IC50 6.65 ± 0.11 μg/mL) and the n-hexane extracts (IC50 12.6 ± 1.40 μg/mL). This literature confirms the variation of antioxidant activities depending on used extraction solvent. In the case of this study, the highest value of DPPH activity was recorded in methanol extract, which corresponds to the highest values of total polyphenols and flavonoids. This suggests a close relationship between the chemicals and antioxidant activities. This positive

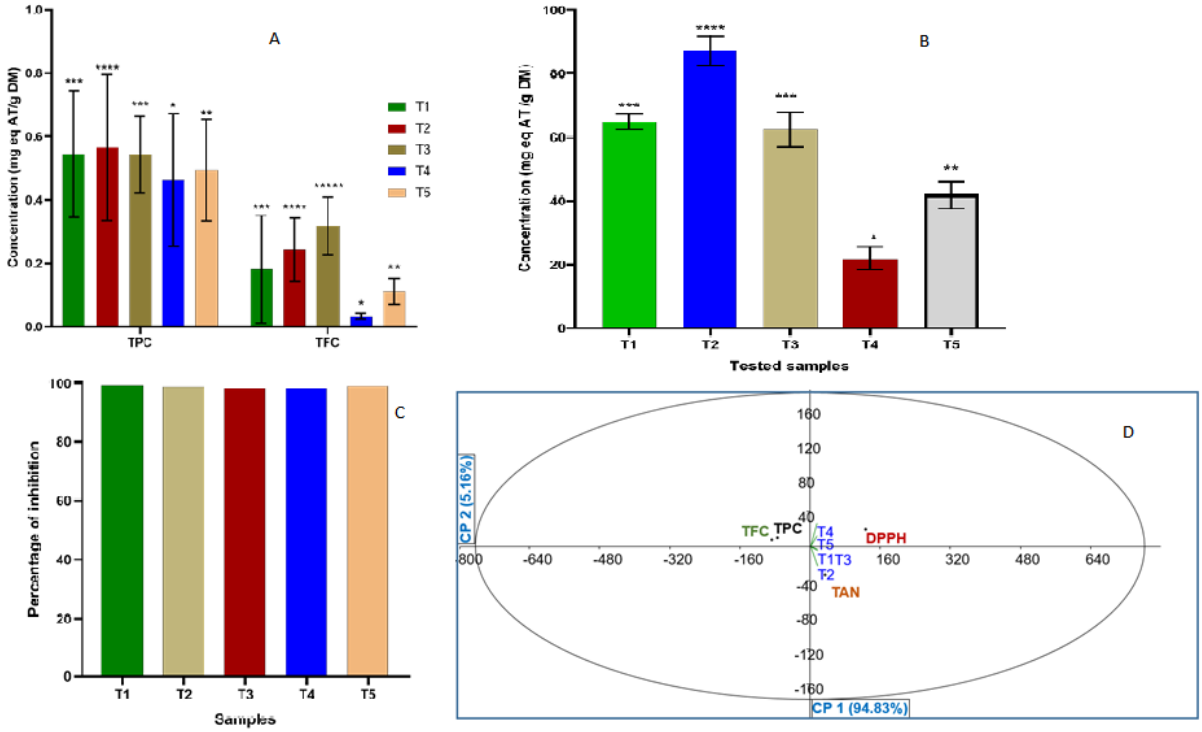

Figure 7. Comparison of Total flavonoid and content polyphenol (A), Tanin compound (B), Antioxidant activity (C), and Principal component analysis (D) of the relationship between chemicals (Total Polyphenols (TPC), Flavonoid (TFC), and Tannin (TAN) Contents) and extracts of *Cymbopogon citratus*

relationship between chemical compounds and antioxidant activity was recorded in previous studies[46]. demonstrated a positive correlation between total phenolic content and antioxidant activity in ethanol extracts from leaves of *Garcinia schomburgkiana*. Ganji et al. [47] investigated the total polyphenols and antioxidant activity in methanolic extracts of the powdered peels of the commercial melon (*Cucumis melo*) and recorded a significant positive correlation between polyphenols and antioxidant activity. Lim et al. [48] demonstrated a significant positive relationship between antioxidant activity, total phenolic, and total flavonoid content of *Phaleria macrocarpa* fruits. In our case, the antioxidant activity is suggested to be related to the quantity of total chemicals and flavonoids as mentioned by a wide range of studies.

Figure 7. Comparison of Total flavonoid and content polyphenol (A), Tanin compound (B), Antioxidant activity (C), and Principal component analysis (D) of the relationship between chemicals (Total Polyphenols (TPC), Flavonoid (TFC), and Tannin (TAN) Contents) and extracts of *Cymbopogon citratus.*

Multivariate analysis

Principal Component Analysis was used to study the association between chemicals (Total Polyphenols (TPC), Flavonoid (TFC), and Tannin (TAN) Contents), antioxidant activity, and infusion of tested products. The results are displayed in a two-dimensional plot (Figure 7D). The outcomes were split into two components, with axis 1's estimated inertia being 94.83% and axis 2's estimated inertia being 5.16%. The infusion of *Cymbopogon citratus* and T5 was principally characterized by higher inhibition of radicals. The infusions of T1, T3, and T3 were principally characterized by higher quantities of Tannin

content. The total polyphenol and flavonoid content were not related to the tested infusions.

Nutritional components

The nutritional value of *Cymbopogon citratus* is presented in Table 1. In total, 5 parameters were evaluated in dry matter and the values were significantly different. In terms of quantity, the total sugar was the most dominant with 0.376 g per g of dry matter of *Cymbopogon citratus*, followed by lipids with 0.106 g per g of dry matter. Citric acid presents 4.22g in 100 g of dry matter of *Cymbopogon citratus*, while the least recorded components were proteins with 0.9 mg /g of dry matter. Further, the Ph of the studied samples was estimated at 6.25.

The nutritional quality of *Cymbopogon citratus* is governed by its chemical and mineral composition. Many studies have addressed nutritional value and the composition of different parts of *Cymbopogon citratus*[49–52]. For example, The nutritional content of Angolan *Cymbopogon citratus*, which is utilized for medicinal purposes, was examined by Soares *et al.* [39] to assess its nutritional value. The results showed that the plant leaves contained various compounds dominated by carbohydrates (60%) and proteins (20%) followed by moisture (9%), fat (5%), and ash (4%), while the phytochemicals screening showed the presence of flavonoids, terpenoids, and tannins. In another study, the leaves of *Cymbopogon citratus* showed significant quantities of moisture, crude protein, ash, crude fiber, and fat[43]. This agrees with the results of this study and explains the nutritional value of *Cymbopogon citratus.*

The lemongrass (*Cymbopogon citratus*) is a medicinal and aromatic plant [53]. In general aromatic, flavours, flavonoids, and essential oils give aroma/smell to the lemongrass extract[15,42]. These properties are closely related to the diversity and quantity of chemical compounds in extracts, essential oils, and infusions of *Cymbopogon citratus* [15,54–57]. This study aimed to investigate the chemical compounds (polyphenols, flavonoids, and tannins) and antioxidant activity in infusions of *Cymbopogon citratus* and four types of tea, then sensory evaluation of their infusions was realized. The obtained results showed a significant number of total flavonoids, polyphenols, and tannins in infusion from the leaves of *Cymbopogon citratus*. The leaves of the plant contain a higher value of proteins and sugars. Equally, the sensory evaluation demonstrated positive findings.

Table 1. Nutritional components and pH of *Cymbopogon citratus*

Parameters	Quantity (g /g DM)	Percentage
Lipids	0.106	10.6%
Protein	0.009	0.09%
Total sugar	0.376	37.6%
Citric acid	0.0422	4.22%
pH	6.25	

Conclusion

Cymbopogon citratus, commonly known as lemongrass, is a fragrant and therapeutic plant. Chemical compounds and flavors generally contribute to the aroma and smell of lemongrass extract. The variety and amount of chemical components found in *C. citratus* extracts, essential oils, and infusions influence directly these characteristics. In this study, we tested the sensory properties of infusions prepared from leaves of *C. citratus* and we compared them to the tea commonly used in Morocco. Then, we evaluated the chemical compounds including polyphenols, flavonoids, and tannins and antioxidant activity of infusions to relate between content and sensory quality. The obtained results showed that infusions of *C. citratus* were the most selected compared to the tea. Lemongrass green tea exhibited teeth incises, strength, color, taste, and sweetness. These properties were related to the chemical compounds including flavonoids, polyphenols, and tannins in infusion from the leaves of *Cymbopogon citratus*. Equally, the leaves of the plant contained a higher value of proteins and sugars. These results are of great importance for the food uses of *C. citratus*. However, more investigations are needed to explore more formulas for the use of the plant in food and traditional uses based on its chemical richness.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Ethical note

The ethical requirements were respected during the comparative tasting experience between lemongrass herbal teas and herbal teas from 4 varieties of tea marketed in Morocco which took place at the headquarters of the functional ecology and environmental engineering laboratory at the Faculty of Sciences and Technology of Fez.

During the experiments, participants were informed about the purpose of the experiment, procedures, and potential risks. The legal requirements of the National Food Safety Office (ONSSA) have been respected. Participants' data were collected and stored confidentially, and anonymity was guaranteed. There were no vulnerable people, such as minors, the elderly, or people with health problems. The experiment was carried out under adequate hygiene and safety conditions, and participants were protected against any risk of contamination or injury.

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