Ethnobotanical study of *Cymbopogon citratus* (Lemongrass) in Northern Morocco: Traditional uses and phytochemical composition

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Research

Abstract

Background: *Cymbopogon citratus* (Lemongrass) offers a variety of medicinal, recreational, culinary, and cosmetic benefits to consumers worldwide, largely shaped by local traditions and ways of life. However, little research has explored how people in Northern Morocco utilize this plant, and its chemical composition in the region has seldom been documented.

Methods: A questionnaire was developed to assess awareness, use, cultivation, and storage of lemongrass and was administered through face-to-face interviews with 46 residents of the Tangier metropolitan area. Quantitative data were analyzed descriptively, and qualitative responses were examined using thematic analysis. The chemical composition of a local lemongrass sample was determined by gas chromatography–mass spectrometry (GC-MS).

Results: Two-thirds of participants were aware of lemongrass, with about 56% using it in their diets and one-third cultivating it. The most common use involved mixing it with other ingredients to prepare Moroccan tea, home-cooked meals, or traditional remedies for colds, flu, and digestive discomfort. GC-MS analysis revealed 25 distinct components, with geranial (34.47%), neral (28.96%), and α-myrcene (18.8%) as the major constituents.

Conclusions: The use of *Cymbopogon citratus* in Northern Morocco aligns with cultural practices observed elsewhere in Africa and Asia. The chemical composition supports its traditional medicinal applications and suggests opportunities for commercialization that could benefit both the local economy and traditional medicine. This study lays the groundwork for future comparative analyses of lemongrass use worldwide, offering insights for policymakers and scientists interested in sustainable and culturally grounded medicinal plant utilization.

Keywords: *Cymbopogon citratus*, Lemongrass, Consumer Use, Survey Research, Morocco, Chemical composition, Ethnobotany

Background

The Kingdom of Morocco is home to plenty of medicinal plants, offering great opportunities for clinical research, as well as drug discovery (Bouribab *et al.* 2024). One of the most therapeutic plants in Northern Morocco is lemongrass (*Cymbopogon citratus*), which belongs to the Poaceae family (El Ouafi *et al.* 2023). *Cymbopogon citratus* has a strong scent with sharp-edged, long, thin green leaves (Shahdeo *et al.* 2023; Yayuk *et al.* 2024). Local populations in the northern part of Morocco have used the plant in their cuisine, medicinal practices, and cosmetic industries (Tazi *et al.* 2024). Lemongrass has emerged as a primary ingredient in the treatment of the flu, COVID-19, and strep throat infections (Nayaka *et al.* 2023; Watuguly *et al.* 2022). Additionally, the plant has become a common part of therapies addressing bacterial and viral infections, including cough, soreness, and nausea (Subramaniam *et al.* 2020). Lemongrass contains 72 bioactive molecules (Tazi *et al.* 2024). Major components of the plant feature "geranial, neral, geraniol, limonene, and β-myrcene" (Du *et al.* 2024; Khasanah *et al.* 2024; Omoboye *et al.* 2024). Figure 1 presents an image of lemongrass typically found in northern Morocco.

Figure 1. Lemongrass (*Cymbopogon citratus*) typically found in Northern Morocco (Photo RW Bussmann)

Additional phytochemical analyses have identified alkaloids (including methaheptanol, 1.8-cineole, and menthol) in the rhizomes, steroids (β-sitosterol, triacontanol, fucosterol), and various flavonoids (luteolin, cynaroside, O-rhamnosyl isorientin, hydroquinone, quercetin, kaempferol, apigenin, isoscoparin, chlorogenic acid, caffeic acid, and orientin) throughout the plant tissues (Bussmann & Ajjoun 2024). The presence of these diverse bioactive compounds explains the plant's wide range of therapeutic applications across different traditional medicine systems.

Lemongrass is common in tropical and semi-tropical environments (Kiełtyka-Dadasiewicz *et al.* 2021; Bajaj & Naaz 2023). Many regions around the world feature a different variety of plants (Joy *et al.* 2006; Vergis *et al.* 2015). Studies demonstrated that there are at least 55 species of lemongrass around the world with large concentrations in Asia, Africa, and South America (Abdulazeez *et al.* 2016). For instance, *C. schoenanthus* is the common type of lemongrass observed in North Africa (Abdulazeez *et al.* 2016).

Past research has demonstrated the potential of lemongrass as an active agent in food preservation (Ekpenyong & Akpan 2017; Valková *et al.* 2022; Soares *et al.* 2020). More specifically, Do *et al.* (2021) argued that citral, which is a main component of lemongrass oil, prevents microbial activity leading to food decay. Besides citral, which supplies lemongrass with its strong lime scent, the plant contains a variety of components with antifungal and antioxidant properties and benefits (Adukwu *et al.* 2016; Pan *et al.* 2022; Zhang *et al.* 2022). Mukarram *et al.* (2021) found that other ingredients in lemongrass include myrcene, citronellol, methyl heptanone, dipentene, geraniol, limonene, geranyl acetate, nerol.

Cymbopogon citratus is a perennial, shortly rhizomatous grass with culms that can reach up to 2 meters tall and approximately 4 mm in diameter. The plant features glaucous leaf blades measuring 30–90 cm in length and 0.5–2 cm in width, with a characteristic farinose coating below the nodes. Flowering typically begins in January and February, with fruit development occurring in March and April. The plant is generally propagated through seeds, vegetative propagation, and rooted slips (Bussmann & Ajjoun 2024). While *C. citratus* is the variety most commonly cultivated worldwide, *C. schoenanthus* (L.) Spreng. represents the native North African variety, featuring a more compact tufted growth habit with culms 20–120 cm high and filiform to flat leaf blades (Bussmann & Ajjoun, 2024).

One of the advantages lemongrass offers consumers is the rich, nutritious value of the plant. For every 100 grams of lemongrass, there are 99 calories free of cholesterol (Silva & Bárbara, 2022). Lemongrass contains a large amount of fiber (75 grams per 100 grams of the plant) (Suttisansanee *et al.* 2023). Folates are beneficial in enhancing the health of babies by decreasing the risks of developing abnormal neural tubes (Pratamaningtyas *et al.* 2020; Subagio & Lintang, 2023). Lemongrass also contains a plethora of important vitamins, including B1, B5, and B6. By the same token, lemongrass and its products are abundant in potassium, zinc, calcium, iron, manganese, copper, and magnesium (Adhikary *et al.* 2024; Kasole *et al.* 2019).

Globally, lemongrass has been documented in traditional medicine systems across multiple continents. In South American countries, particularly Peru, fresh or dried leaves, roots, and stems are used to treat cold, cough, flu, stomach pain, colic, varicose veins, and to improve blood circulation. The plant has been incorporated into cancer treatment protocols and anxiety management (Bussmann & Ajjoun, 2024). In Madagascar, lemongrass serves primarily as a fever treatment (Bussmann & Ajjoun, 2024), while in Nepal and India, it addresses gastrointestinal disturbances, prevents platelet aggregation in diabetes management, and treats headaches, pneumonia, and serves in aromatherapy applications (Bussmann & Ajjoun, 2024). The root juice is applied to treat pyorrhea in Nepali traditional medicine (Bussmann & Ajjoun, 2024). In African countries, medicinal applications focus on backache, sprains, and hemoptysis treatment (Bussmann & Ajjoun, 2024). These global patterns provide a comparative framework for understanding lemongrass use in Northern Morocco.

Despite the emerging interest in studying lemongrass within Morocco, little systematic research has addressed how local populations in the northern cities and countryside actually utilize the plant. Additionally, the analysis of chemical composition of lemongrass in northern Morocco is limited. None of the studies has documented culinary, therapeutic, medicinal, and recreational uses of the plant. Therefore, the present study offers readers an opportunity to understand how real people use lemongrass in their daily lives. Further, this research provides original chemical composition data from a sample of local lemongrass plants found in the Tangier metropolitan area in northern Morocco.

The primary aim of the present study is to survey the local population in northern Morocco about the uses of lemongrass. More specifically, the study presents original input on how ordinary people living in Tangier and its Metropolitan area utilize lemongrass in cooking, medicine, recreation, and other domains in life. A secondary objective driving the research is to analyze the chemical composition of the local varieties of lemongrass. Therefore, the underlying research questions guiding this research are how do local people in northern Morocco utilize lemongrass? And what are the key chemical components of northern Moroccan lemongrass? Relatedly, how do local people in northern Morocco cultivate, store, and view lemongrass? Answering the aforementioned questions contribute to the current understanding of the value and potential commercialization of lemongrass for beneficial uses around the globe.

A total of 46 participants completed the face-to-face field interviews with the researchers in January 2025. Approximately 66% of all participants indicated some awareness related to lemongrass. One third of all participants reported growing the plant. Purchasing the plant from the marketplace or growing the plant at home were the most common acquisition methods with approximate equality in proportion among participants. Fresh lemongrass was the most consumed form of the plant followed by essential oil and dried leaves. The most application domain of lemongrass among locals in Northern Morocco concerned the cuisine and traditional home-cooked meals followed by medicinal and cosmetic uses. The most common method of using lemongrass was blending the plant with tea for medicinal and recreational uses.

Using the Gas chromatography/mass spectrometry (GC/MS) analysis applied on a lemongrass plant, the chemical composition generated 25 distinct elements. The three most common components were geranial: 34.47, neral: 28.96 and α-myrcene: 18.8. Respectively, the analysis was able to cover 99.07% of the plant. The breakdown of the components was monoterpene hydrocarbons: 21.47%, oxygenated monoterpenes: 69.99% and others: 7.61%.

The present study contributes to the understanding of how local people utilize traditional plants such as lemongrass. While this research corroborates findings from earlier studies through reporting the use of lemongrass in medicine or the kitchen, the paper presents new information on how ordinary citizens utilize the plant in new ways. For instance, participants shared new blends and infusions involving lemongrass with other plants like mint or *Aloysia*. The thematic analysis literature based on the qualitative findings provide rich examples and illustrations of how local people in northern Morocco utilize lemongrass. Another contribution is the discovery of comparative uses of the plant through juxtaposition the findings from this research against results based on samples from other countries.

Materials and Methods

Study area

The present ethnobotanical study was conducted in the northern region of Morocco, a culturally rich and ecologically diverse area known for its unique traditional practices and widespread use of medicinal plants. This region includes the provinces of Tangier-Assilah, Larache, Tétouan, Chefchaouen, Al Hoceima, Ouezzane, M'diq-Fnideq, and Fahs-Anjra. These provinces represent both urban and rural communities, offering a broad understanding of how *Cymbopogon citratus* (lemongrass) is cultivated, used, and stored across different settings. The map in Figure 2 situates the study region within the Kingdom of Morocco, providing geographical context for the interviews and field visits that were conducted throughout the northern territories.

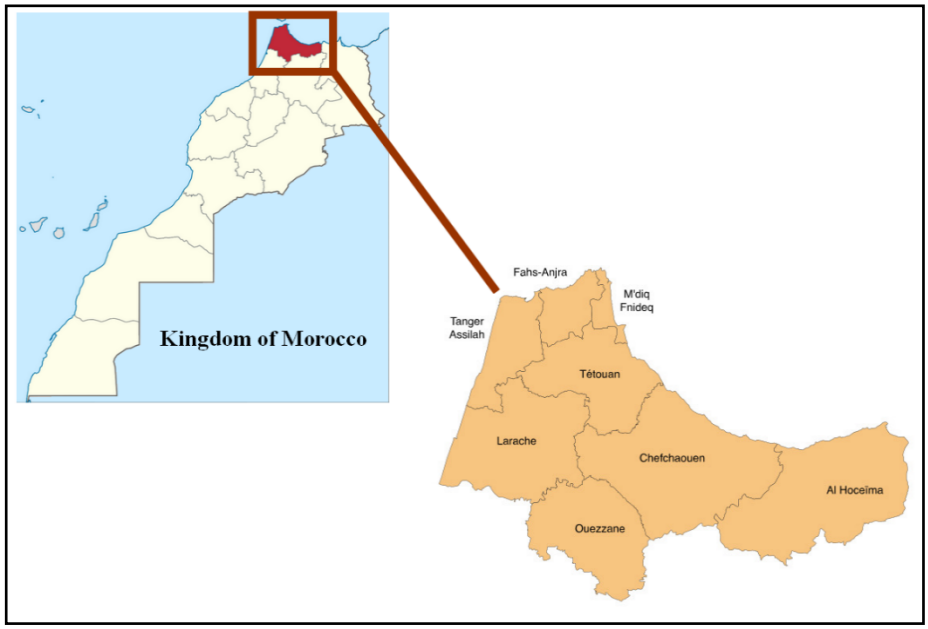

Figure 2. Map of Northern Morocco highlighting the study area (Wikimedia Commons, n.d. https://commons.wikimedia.org/wiki/File:Région_de_Tanger-Tétouan-Al_Hoceima.svg)

A mixed methods research design guided the performance of the current study. On the one hand, quantitative analysis constituted part of the research collecting information about the participants and their use patterns of lemongrass through

surveys. Additionally, a quantitative chemical composition analysis uses gas chromatography and mass spectrometry was used to uncover Moroccan lemongrass elements reporting percentages and frequencies. On the other hand, qualitative analysis guided the collection of open-ended data on participants' views about lemongrass.

Participants

A total of 46 participants completed the questionnaire in this research. The most common age groups represented in the sample were 18-30 and 31-45 categories with 19 and 13 participants in each respectively. The least represented age groups in the sample were 46-60 and over 60 years of age categories with eight and six participants each respectively. The distribution of sexes in the sample was approximately even with 26 male participants and 20 female respondents.

With respect to the residence of participants, 37 individuals reported living in an urban area while nine people chose the rural residence category. Participants reported 11 distinct employment sectors or statuses. The most common response to the employment sector/status question was student with 13 individuals choosing such an option. The next three most common occupations were: Agriculture, forestry, fishing, and hunting, manufacturing, and homemakers each with nine participants. Note that all homemakers in the sample were women.

With respect to education, the most common category of respondents was master's degree (17 individuals). High school graduates comprised the second largest group with 13 participants. Nine people indicated a less than high school education. Further, three people reported having a Ph. D. while four participants possessed a bachelor's degree. Table 1 presents the demographic characteristics of the 46 participants who took part in the ethnobotanical survey, including age, gender, place of residence, employment sector, and educational background.

Table 1. Demographic Characteristics of Study Participants

	Categories	Frequencies	Percentages
Age	18-30	19	41.3
	31-45	13	28.3
	46-60	8	17.4
	>60	6	13.0
Gender	Male	26	56.5
	Female	20	43.5
Residence	Urban	37	80.4
	Rural	9	16.6
Employment industry	Retired	1	2.2
	Unemployed	1	2.2
	Agriculture, Forestry, Fishing, and Hunting	6	13.0
	Manufacturing	6	13.0
	Retail	5	10.9
	College, University, and Adult Education	2	4.3
	Primary/Secondary Education	4	8.7
	Health Care and Social Assistance	2	4.3
	Homemaker	6	13.0
	Student	13	28.3
Education	Grammar School	9	19.6
	High School or equivalent	13	28.3
	Bachelors	4	8.7
	Master's Degree (MS)	17	37.0
	Doctoral Degree (PhD)	3	6.5

Data collection

Face to face interviews facilitate the data collection for the present research. Participants are more willing to share accurate information with researchers in face to face settings compared with online data collection (Kasole *et al.* 2019). More importantly, face to face interviews allow researchers to build trust and rapport with participants opening further communication avenues, resulting in more detailed narratives. Most importantly, face to face survey data collection result in more reliable and valid responses compared with mail or digital data collection efforts (Jain 2021; Knott *et al.* 2022).

To collect information on how lemongrass is cultivated, used, stored, and perceived by local populations in northern Morocco, a new questionnaire was developed by the researchers based on the objectives of the research. Appendix A showcases the questionnaire and the wording of each item. Section one of the questionnaire collects demographic information about the participants. In this section, the style of questions was close ended. The second section of the questionnaire concerns participants' awareness of lemongrass. In this section, participants are asked a mix of closed and open ended questions regarding their familiarity with the plant and its most common uses.

The third section of the questionnaire constitutes the most important part of the survey covering lemongrass uses. On the one hand, participants are asked whether they utilize the plant in traditional common uses such as in culinary, therapeutic, medicinal or recreational activities. On the other hand, participants are given the chance to share more specific uses in open ended questions. The fourth section of the questionnaire concerns the preservation and storage of the plant. Participants are asked about the different methods used to conserve lemongrass.

Field interviews represented the main data collection method for the study. One trained researcher performed all interviews in the Arabic language. Each interview lasted for about an hour. The interview entailed a structured format where the researcher presented a description of the project, the interview proceeded to complete a prepared questionnaire with close and open-ended questions. Lastly, the participant had a chance to share information at the end of the interview. Note that the interviewer informed all participants that each of them will receive a copy of every research product arising from the project.

Data Analysis

Descriptive analysis was used to analyze the survey quantitative data. Frequency and relative frequency analysis were performed to summarize the proportions of individuals who use, grow, or purchase lemongrass. Relatedly, the sane type of analysis was used to describe the percentages of participants who reported the utilization of the plant for a variety of reasons.

To examine the qualitative information in the research, the researchers employed thematic analysis. First, the researchers prepared a single document containing all open-ended answers. The document featured each question and the respondents' written answers. Each researcher read the document twice independently to establish familiarity with the information prior to performing the data analysis. Then, each researcher prepared a list of codes summarizing each response in the document. A code refers to a basic underlying idea within a textual bloc. The bloc could be a single sentence or a group of sentences. In a joint session, the researchers compared the lists of codes to ensure consistency. Minimal differences existed between the lists, and the researchers agreed on the labeling of codes during the sessions.

Following the preparation of the final codes list, the researchers met again to classify the codes into themes. Each set of related codes represented a theme. Once the researchers assigned each code to a separate theme, the researchers prepared a table containing the final set of themes, their codes, and illustrative quotes from the interviews representative of the codes. Finally, the researchers fully described each theme in detail to be included in the results section of the present research.

Multidimensional Scaling (MDS) guided the multivariate analysis portion of the research. MDS reduces the complexity of the data by summarizing a large number of variables into a few dimensions. Dimensions refer to meaningful factors that explain links between a related set of factors. For instance, a survey question asked participants to indicate *Cymbopogon citratus* use in treating health conditions offering 11 different conditions. MDS attempts to reduce the 11 into a few dimensions that summarize relationships between the 11 original conditions. The MDS output comprise visualizations that demonstrate the dimensions, their labels (assigned by researchers), and the distribution of the original variables on the new dimensions.

Plant Material Collection and Essential Oil Extraction

Fresh aerial parts of *Cymbopogon citratus* were collected in December 2024 from the Had Lgharbiya region of Tangier, Morocco. The plant material was identified and authenticated, and the harvested samples were subjected to a controlled drying process at 40°C under continuous ventilation for 48 hours. Once dried, 2 kg of plant material (leaves) was used for essential oil extraction.

The extraction was carried out using hydrodistillation in a Clevenger-type apparatus. The dried leaves were placed in a distillation flask containing distilled water, and the mixture was boiled for two hours. The resulting essential oil was collected

and stored in amber vials to prevent degradation. The extraction yield was calculated at 1.87% (w/w). To ensure the stability and integrity of the volatile compounds, GC-MS analysis was performed on the same day as the extraction.

Gas chromatography/mass spectrometry (GC/MS) analysis

The study employed GC-MS as an analytical method to identify the chemical constituents of *Cymbopogon citratus* essential oil. The *Cymbopogon citratus* essential oil analysis was performed using a Thermo Scientific TRACE-1300 series GC system, coupled with a Triple Quadrupole Mass Spectrometer (TSQ 8000 Evo) (Thermo Fisher Scientific Inc., Austin, Texas, USA). A fused silica TR-5 capillary column (30 m × 0.32 mm I.D.; 0.25 µm film thickness) was utilized for separation. The temperature program began with an initial hold at 70°C for 4 minutes, followed by a gradual increase to 180°C at a rate of 4°C per minute, and was subsequently maintained at 300°C for 20 minutes.

Samples, diluted in hexane, were manually injected (1 µL) in splitless mode. Helium served as the carrier gas with a flow rate of 1.5 mL/min. The injector and detector temperatures were set at 200°C and 250°C, respectively. Mass spectra were recorded over a scan range of 40–700 amu, with a scan rate of five scans per second. Compound identification was achieved through a combination of retention index data and mass spectral matching against the NIST/EPA/NIH Library Version 2017.

Results

Two thirds of the sample indicated a level of awareness concerning lemongrass. One third of participants were unaware of lemongrass. Among those who are aware of lemongrass, about half of them reported growing the plant. In other words, one third of the entire sample including those who are aware and unaware of lemongrass reported growing the plant. In sum, one third of the 46 participants are unaware of the plant and do not grow it. Another third of participants are aware of lemongrass, yet they do not grow it. Finally, the remaining third of participants are aware of lemongrass and grow the plant (Figure 3).

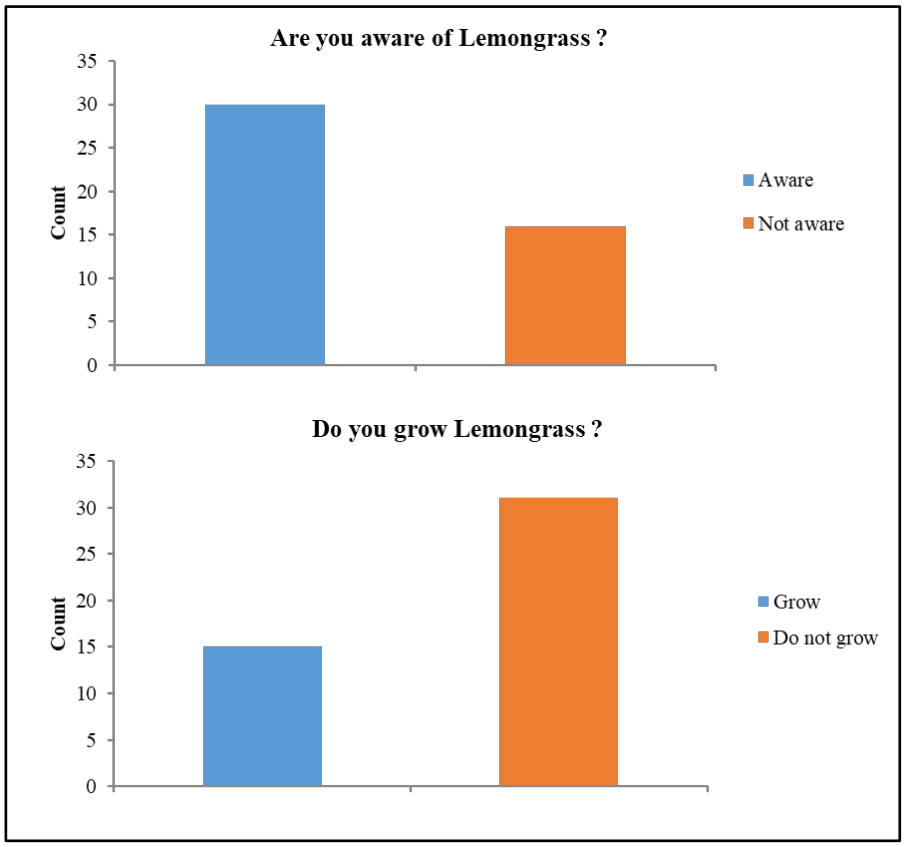

Figure 3. Participants' awareness of Lemongrass and responses to the cultivation of Lemongrass

Participants were asked whether they used lemongrass or not in their daily lives. Most people who are aware of lemongrass consume the plant (26 participants). On the other hand, four participants indicated that they do not use lemongrass. More broadly, about half of all participants in the survey reported the use of lemongrass in one form or another (Figure 4).

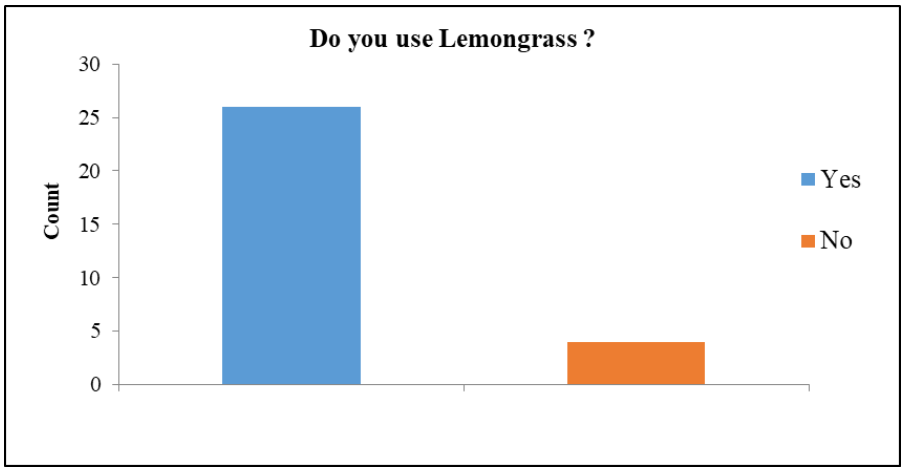

Figure 4. Participants' Responses to the use of Lemongrass

Participants reported a wide range of lemongrass forms consumed at their homes. The most common form of lemongrass was fresh plants homegrown, purchased, or picked up from nature (eight participants). The second most popular form of lemongrass was essential oil, with five individuals choosing such a form. The third most common form was dried lemongrass with four participants selecting the choice. Infusion was the fourth most common choice with three participants. Notably, some participants selected more than a single form of lemongrass (Figure 5).

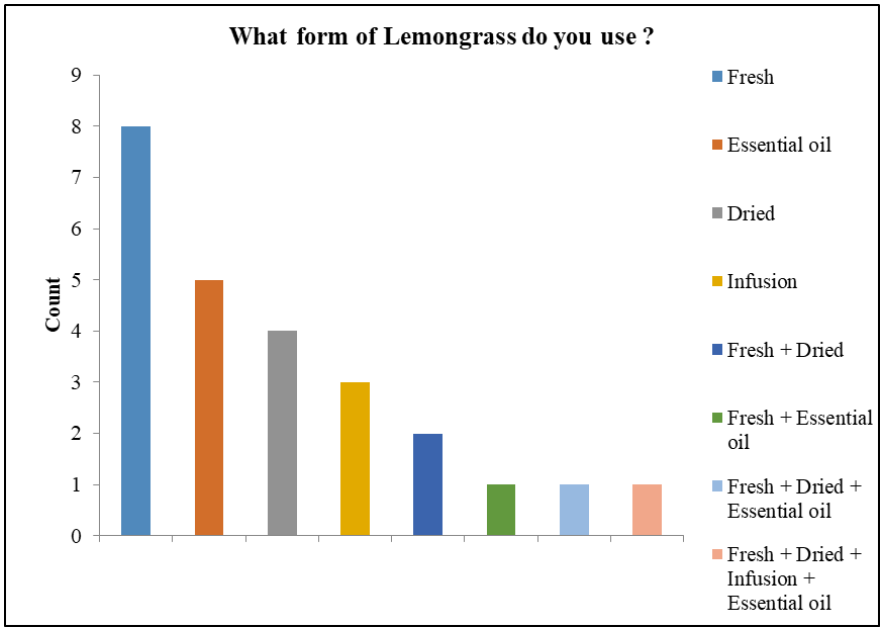

Figure 5. Forms of Lemongrass use by participants

Participants vary with respect to lemongrass use. The most common usage of the plant was in the preparation of home meals and the traditional Moroccan cuisine (eight participants). The second most common utilization of lemongrass was for medicinal purposes (five participants). Three individuals indicated the use of lemongrass for cosmetic purposes. Most participants, however, reported the use of lemongrass in more than a single realm in their lives (Figure 6).

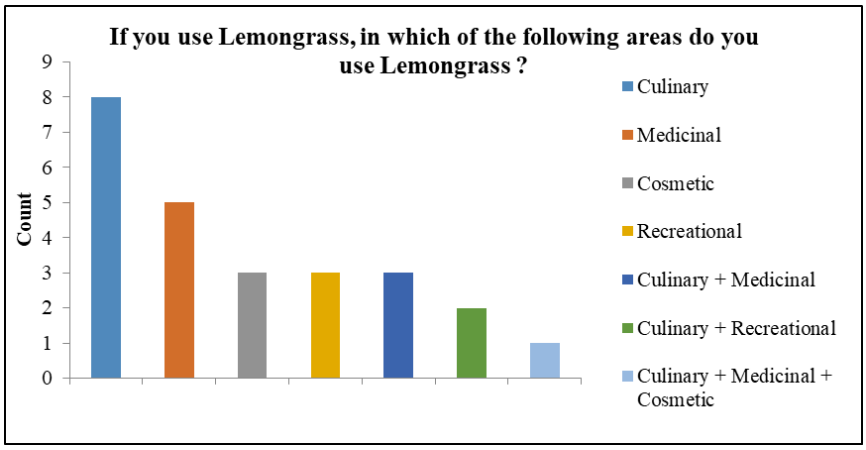

Figure 6. Reported Areas of Lemongrass Use by Participants

Respondents expressed various methods of obtaining or cultivating lemongrass. The most common acquisition was to purchase the plant from the marketplace (13 participants). The second most common way was to grow the plant at home (12 participants). Theun least attainment technique of the plant was to pick lemongrass from the ground in the wild (one person). In sum, participants reported a variety of ways concerning how lemongrass is cultivated or acquired (Figure 7).

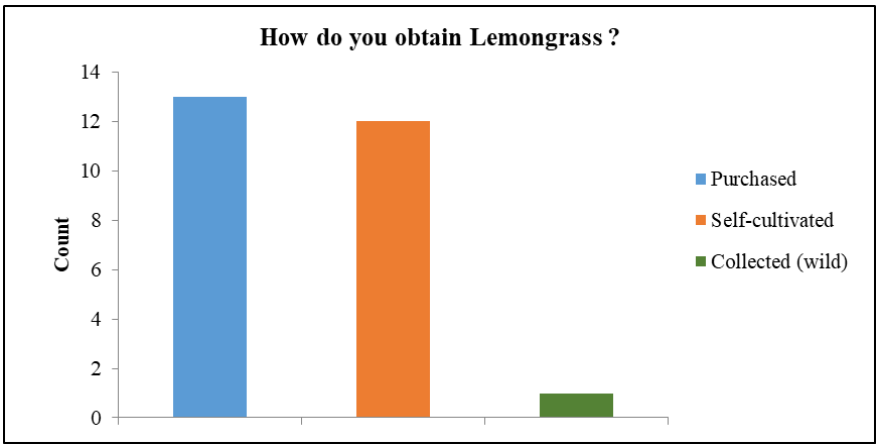

Figure 7. Sources of Lemongrass acquisition among participants

Respondents expressed a variety of cultivation ways for consumed lemongrass. The most common method of cultivation was growing the plant at home (nine participants). The second most common way was purchasing the plant commercially from the marketplace (three participants). The least reported choice of cultivation was picking the plant from the ground in the wild (one individual). In sum, participants cultivated lemongrass in numerous methods (Figure 8).

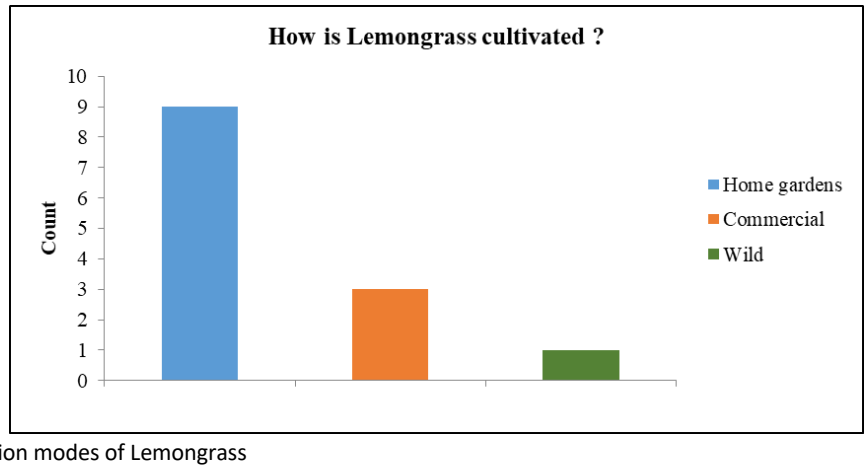

Figure 8. Cultivation modes of Lemongrass

Respondents utilize various forms of lemongrass for medicinal purposes. On the one hand, infusion appeared to be the most common method among Moroccans (18 participants). The most common method of infusion is blending lemongrass with tea along other herbs such as mint. Additionally, participants indicated the use of lemongrass essential oil for medicinal purposes (three individuals). Two people suggested the use of lemongrass paste to treat illnesses or symptoms. Note that some participants indicated the use of more than a single form of lemongrass to treat medical conditions (Figure 9).

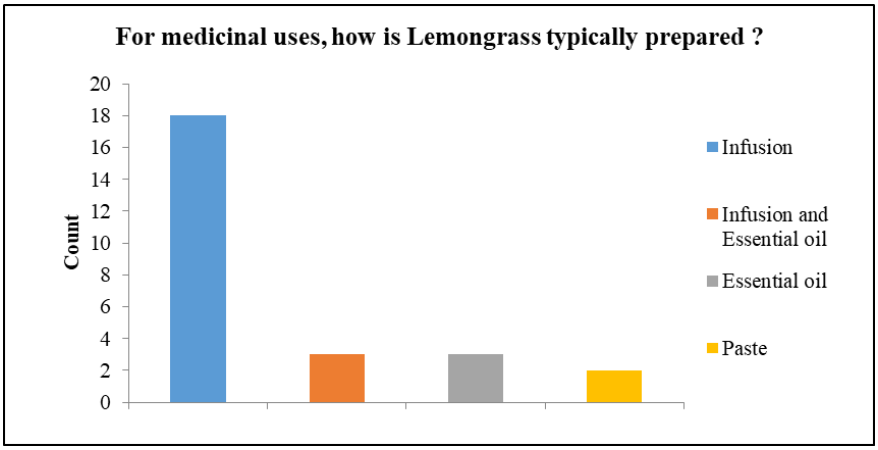

Figure 9. Common preparation methods of Lemongrass for medicinal purposes

Among the 46 participants surveyed in Northern Morocco, a significant number reported using lemongrass for treating various health conditions. As shown in Figure 10, digestive issues emerged as the most frequently treated ailment, with eight participants citing it as the primary reason for using lemongrass. Anxiety and stress were also commonly addressed using lemongrass remedies, with six individuals highlighting its calming properties. Insomnia, muscle pain, and fever followed, each reported by four or fewer participants. Less common but still notable applications included the treatment of infections and menstrual cramps.

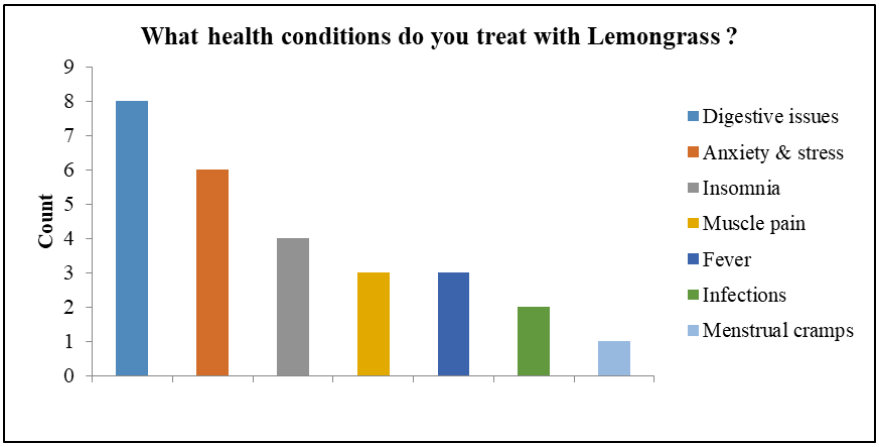

Figure 10. Health conditions treated with Lemongrass

Barriers to lemongrass use

Participants suggested a variety of reasons for not using lemongrass. Three themes emerged from the responses: Limited awareness, presence of alternative options and undesirable characteristics of lemongrass. On the one hand, respondents indicated a modicum of unfamiliarity of the plant. For instance, one participant stated that "*Honestly, I never thought about using it. It is not something common in our household.* "Additionally, participants expressed the limited need for using lemongrass because other equally potent herbs are available in the marketplace. For instance, one respondent stated that "*We mostly rely on other traditional herbs like mint, thyme, and verbena.*" Finally, a few participants described lemongrass as an undesirable option in the marketplace citing numerous negative characteristics for the plant. For example, one participant indicated that "*I do not like the taste of lemongrass because it has a strong citrusy flavor that I find too overpowering in teas or food*". Table 2 summarizes participants' open-ended responses regarding barriers to lemongrass use and common preparation methods.

Table 2. Themes and Sub-Themes from Open-Ended Survey Responses on Barriers and Preparation Methods of Lemongrass

Themes	Sub themes
Limited awareness	Lack of use at home
	Absence of awareness
Presence of alternative options	Existence of alternative herbs
	Plethora of equally available options
	Limited market availability of lemongrass
Undesirable characteristics of lemongrass	Dislike strong citrusy taste
	Lack of interest

Traditional uses of lemongrass

Respondents suggested a wide range of lemongrass uses, mixtures, and purposes. Five themes emerged when Respondents were asked to share their traditional uses and receives involving lemongrass: Medicinal purposes, preparation method, unique mixtures, cooking purposes and home uses. Medicinal purposes included the treatment of the digestive system, cold, stress, and skin disorders. For instance, one Respondent indicated "*We boil lemongrass with mint and thyme for digestion.*" Additionally, participants suggested a variety of home use recipes for lemongrass. One popular use was to "repel insects" from the home. One of the most interesting results in this research is the plethora of unique mixtures lemongrass has in Morocco. Respondents indicated 10 ways lemongrass is mixed with other herbs or ingredients such as mint, thyme, honey, chamomile and cloves (Table 3 provide a full list of mixtures). Many participants indicated mixing lemongrass with other herbs to prepare tea in a variety of forms. For instance, a participant stated, "*We mix lemongrass with green tea and louiza (Verbena) for a calming effect.*" Finally, participants suggested numerous preparation methods for lemongrass including traditional cuisine, use to prepare tea, use in seafood dishes, chewing raw lemongrass for taste, energy booster, sellou, meat marinades and preparing soups. For example, one respondent indicated "*We use it in chicken tagine for a fresh citrusy taste.*"

Table 3. Themes and sub-themes from open-ended survey responses on traditional uses of Lemongrass

Themes	Sub-Themes
Medicinal purposes	Digestive system symptoms remedies
	Treating cold
	Bloating and stress
	Headache
	Insomnia
	Wounds treatment
	Muscle pain relief
	Itching reduction
	Sore throats
	Hair growth
	Feet soaking
	Skin treatment
Preparation method	Boiling water mixed with other herbs
	Infusion with tea
	Detox drinks
	The use of raw fresh lemongrass
	Lemongrass essential oil
	Crushing fresh lemongrass
	Lemongrass water (toner)
Unique mixtures	Mint and thyme
	Honey and black seeds
	Lemon and ginger
	Tea and verbena
	Chamomile
	Cloves and cinnamon
	Fenugreek and honey
	Sugar and lemon

	Olive oil
	Anise
Cooking purposes	Traditional cuisine (chicken tagine)
	Use to prepare tea
	Use in seafood dishes
	Chewing raw lemongrass for taste
	Energy booster
	Sellou (a Moroccan energy mix)
	Meat marinades
	Preparing soups
Home uses	Repel insects
	Aromatic smell

Storage of Lemongrass

Participants shared a variety of ways for storing lemongrass. On the one hand, refrigeration, freezing, and drying were the most common methods of storage. Participants stored lemongrass using plastic bags, glass jars, tin boxes, containers and paper bags. Additionally, respondents indicated placing the bags and containers in kitchen cabinets and drawers. For instance, one respondent indicated "*Putting it in an airtight container keeps it from getting moldy.*" Similarly, another participant stated, "*Placing dried lemongrass in a tin box prevents it from spoiling.*" Despite variability in the answers, drying lemongrass appeared to be the most common method of preserving lemongrass. Table 4 presents the main storage methods and containers reported by participants for preserving lemongrass.

Table 4. Themes and sub-themes from open-ended survey responses on the storage of Lemongrass

Themes	Sub-Themes
Methods of storage	Drying
	Refrigeration
	Freezing
	Hanging for dehydration
	Pantry
	Kitchen drawer
Tools used to store lemongrass	Glass jar
	Damp clothes
	Plastic bag
	Paper bag
	Ziplock bag
	Container
	Cloth bags
	Tin box

Chemical composition

The essential oil extracted from *Cymbopogon citratus* was analyzed by gas chromatography coupled with mass spectrometry (GC-MS) in order to determine its chemical profile. The analysis revealed the presence of numerous bioactive compounds, with variation in their relative abundance. The major constituents identified include monoterpenes and oxygenated compounds, particularly citral (a combination of geranial and neral), which is known for its antimicrobial, anti-inflammatory, and antioxidant properties. These components are primarily responsible for the therapeutic potential and characteristic aroma of lemongrass oil. The detailed chemical composition, including the retention times and relative percentages of each compound, is presented in Table 5.

Table 5. Chemical composition of Lemongrass essential oil Identified by GC-MS analysis

No	tR (min)	Compound Name	Molecular Formula	Area %
1	10.64	Methylheptenone	$C_8H_{14}O$	1.65
2	10.79	α-Myrcene	$C_{10}H_{16}$	18.8
3	12.14	Eucalyptol	$C_{10}H_{18}O$	0.14

4	12.45	α-Pinene	$C_{10}H_{16}$	0.86
5	12.82	Cyclofenchene	$C_{10}H_{16}$	0.57
6	14.48	10-Undecyn-1-ol	$C_{11}H_{20}O$	0.3
7	14.78	Linalool	$C_{10}H_{18}O$	0.63
8	16.10	Hexane, 1-chloro-5-methyl-	$C_7H_{15}Cl$	0.12
9	16.49	Phorone	$C_9H_{14}O$	0.23
10	16.64	Citronellal	$C_{10}H_{18}O$	0.51
11	17.06	Caryophyllene oxide	$C_{15}H_{24}O$	1.2
12	17.44	Acetophenone	C_8H_8O	0.27
13	18.13	Oleic Acid	$C_{18}H_{34}O_2$	0.14
14	19.50	Citronellyl formate	$C_{11}H_{20}O_2$	0.44
15	19.90	Neral	$C_{10}H_{16}O$	28.96
16	20.42	Geraniol	$C_{10}H_{18}O$	5.00
17	20.96	Geranial	$C_{10}H_{16}O$	34.47
18	21.56	2-Undecanone	$C_{11}H_{22}O$	0.46
19	21.83	Geranyl formate	$C_{11}H_{18}O_2$	0.12
20	22.59	Carveol	$C_{10}H_{16}O$	0.29
21	24.48	Geranyl formate	$C_{11}H_{18}O_2$	1.83
22	25.61	Nerolidol	$C_{15}H_{26}O$	0.28
23	26.10	d-Limonene	$C_{10}H_{16}$	1.24
24	27.96	2-Tridecanone	$C_{13}H_{26}O$	0.41
25	30.57	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-	$C_{15}H_{26}O$	0.15
Total :				**99.07%**

Multidimensional Scaling (MDS)

Figure 11 showcases the two dominant dimensions defining the use of *Cymbopogon citratus* in Morocco. On the one hand, many people suggested the use of the plant to treat long-term health conditions whereas others suggested its use for short-term symptoms. Further, Moroccans have used the plant to treat both physical, as well as mental conditions. The most common use of the plant is to treat short-term physical conditions like fevers and headaches. Such a use is consistent with other findings since participants have indicated the infusion of lemongrass in their daily tea drinking habits. The use of the plant to treat long-term mental conditions like chronic insomnia is the least common category of uses.

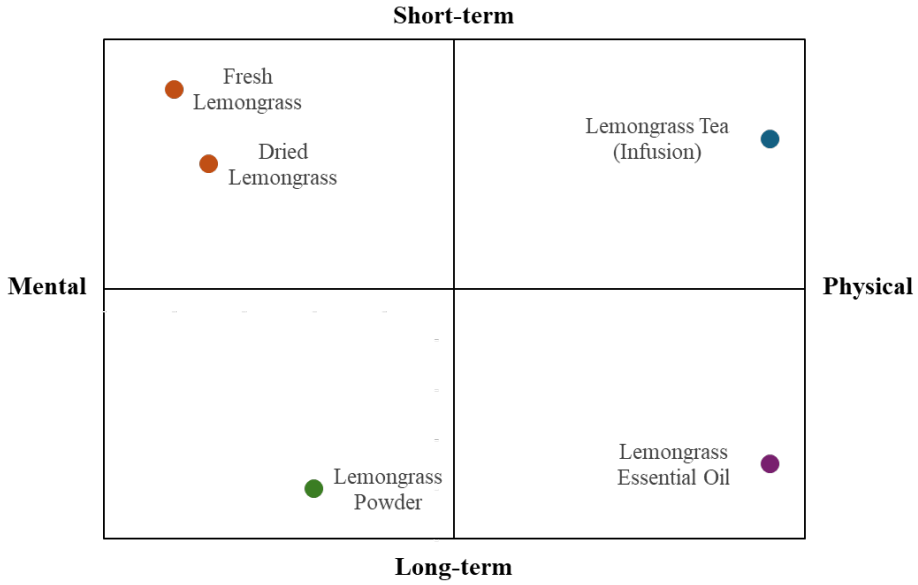

Figure 11. MDS representation of *Cymbopogon citratus* uses in Morocco according to treatment duration (short- vs. long-term) and condition type (mental vs. physical).

Figure 12 showcases the two dominant dimensions defining the use of *Cymbopogon citratus* in Morocco. On the one hand, many people suggested the use of the plant to treat long-term health conditions whereas others suggested its use for short-term symptoms. Further, Moroccans have used the plant to treat both physical, as well as mental conditions. The most common use of the plant is to treat short-term physical conditions like fevers and headaches. Such a use is consistent with other findings since participants have indicated the infusion of lemongrass in their daily tea drinking habits. The use of the plant to treat long-term mental conditions like chronic insomnia is the least common category of uses.

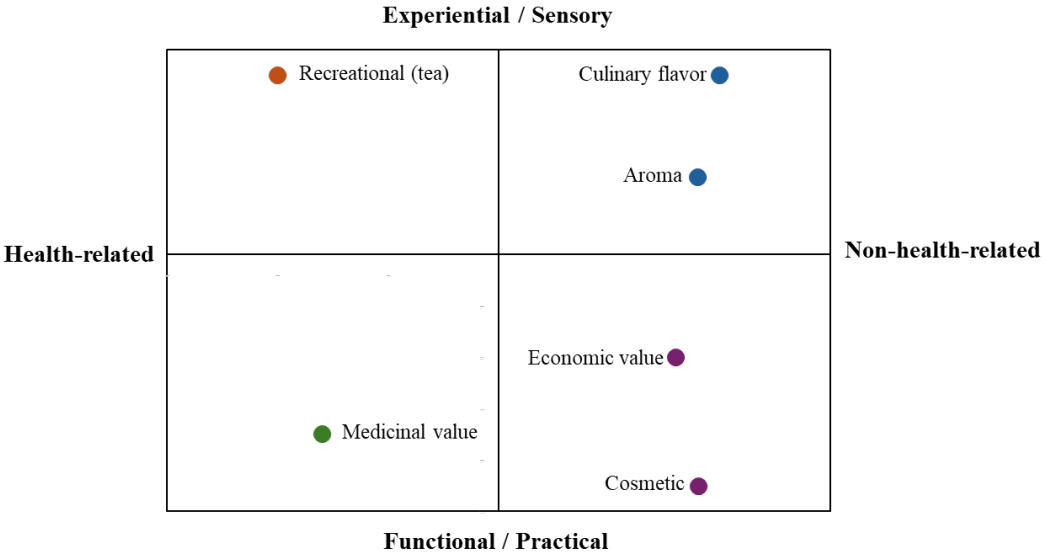

Figure 12. MDS representation of perceived values and uses of *Cymbopogon citratus* in Morocco along health relevance and experiential–functional dimensions.

Figure 13 demonstrates the most common two dimensions defining participant views on the most important properties of *Cymbopogon citratus*. On the one hand, participants suggested the use of the plant for health, as well as non-health related purposes. On the other hand, participants suggested the use of the plant for experiential or functional uses. Non-health related properties of the plant are more emphasized compared to health benefits. Functional and sensory properties appear to be equal in importance in the eyes of participants. Congruent with earlier findings, the culinary and economic value properties appeared to be the most important cited value-added elements of *Cymbopogon citratus* in Morocco.

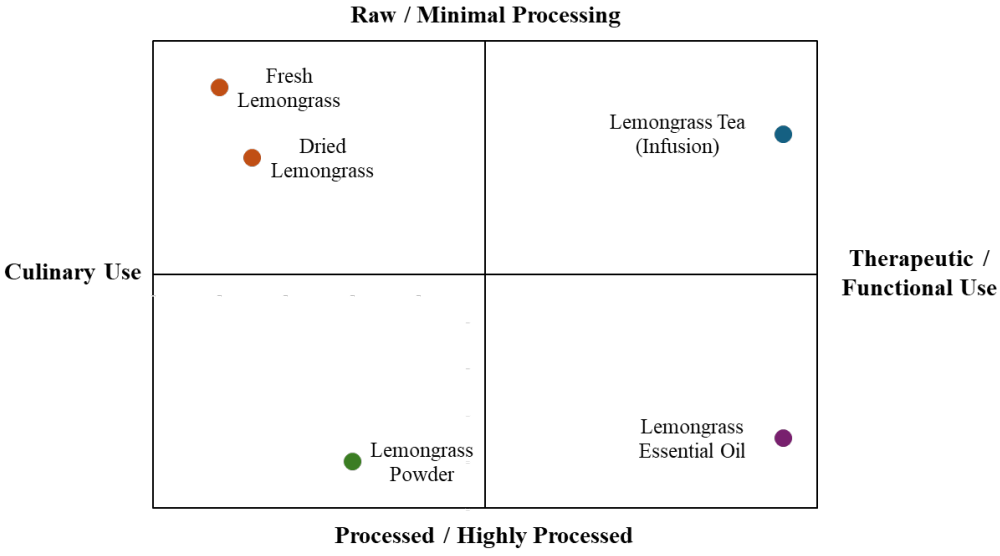

Figure 13. MDS representation of lemongrass forms in Morocco according to processing level and type of use (culinary vs. therapeutic/functional).

Discussion

One of the contributions of the present analysis is the quantification of lemongrass awareness, use, storage, and blends in the literature. Past research has limited insults on population proportions concerning lemongrass (Toungos 2019). Studies of the plant either focused on its chemical properties or medicinal applications (Dagupen *et al.* 2009). This research document that a significant proportion of the population are still unaware of lemongrass in an area where the plant is considered to be known to locals. Such an inference leads to the conclusion that in areas where the plant is less common and used, awareness is much lower. Thus, more education on the benefits and uses of lemongrass and similar herbs is needed to redress such a deficiency.

Moroccans use of lemongrass is similar to other populations around the world. Toungos, M. D. (2019) concluded that lemongrass is typically used in the preparation of the variety of tea in Western and Central African countries. Similarly, the study concluded that many African populations like in Togo, the Republic of the Congo, Nigeria, and others utilize lemongrass in preparing traditional poultry and seafood dishes (Toungos 2019). In a similar study, Dagupen *et al.* (2019) concluded that Fillipinos preferred lemongrass tea over other culinary options offered with the plant (Dagupen *et al.* 2009). The researchers cited consumers' preference to the citral (neral and geranial) properties and aromatic nature of the tea, which were reported among the sample in this study.

The patterns observed in Northern Morocco align with documented uses across Asia, Africa, and South America. Similar to findings from Peru where lemongrass is used to treat cold, cough, stomach pain, and improve blood circulation (Bussmann & Ajjoun 2024), Moroccan participants reported digestive issues and cold treatment as primary applications. The use of lemongrass tea observed in this study parallels practices in Nepal where dry leaves are commonly prepared as tea for cough and cold (Bussmann & Ajjoun 2024). However, the specific blends identified in Moroccan, such as combinations with mint, thyme, verbena, and honey, represent culturally unique preparations that distinguish Moroccan ethnobotanical practices from other regions. The external application of lemongrass oil for skin conditions reported by some participants mirrors uses documented in Nepal and India for treating ringworm, athlete's foot, scabies, lice, dandruff, and acne (Bussmann & Ajjoun,2024).

Another contribution of the present research is the provision of new information on how ordinary people store lemongrass. Past research has demonstrated that drying lemongrass is an acceptable method to preserve the basic properties and chemical structure of the plant (Lonkar *et al.* 2013). In this research, Moroccans utilized drying as the most common method of preserving the plant, which is consistent with what prior researchers recommended. Nevertheless, participants dried fresh leaves without converting the plant into powder as recommended in earlier studies. Before a generic guidance is published on how to properly store the plant, more future research is needed on testing the quality of the plant after storage in different methods using various tools (Mrabet *et al.* 2024).

The present study is offering a comparative perspective on the use of traditional herbs in modern changing societies (Abduljaber, 2018). While the Kingdom of Morocco has developed significantly in the past century (Onder 2019; Onder 2022; Abduljaber *et al.* 2025), local populations still utilize traditional herbs like *Cymbopogon citratus*. The persistent use of traditional medicine and culinary practices notes to the simultaneous presence of both authentic, as well as modern elements within the same social fabric (Abduljaber & Onder 2024). Such an observation paves the way for additional study in Middle Eastern and North African countries to integrate the region into the global scholarship on ethnobotanical research (Maataoui *et al.* 2025).

The present research provided a wide range of medicinal uses of lemongrass among locals in Northern Morocco. The reported uses are consistent with the medical and pharmacological research on lemongrass health benefits. Studies demonstrated the antioxidant potential of lemongrass in treating illnesses through the possession of chlorogenic acid, isoorientin and swertiajaponin (Sharma *et al.* 2021). Further reviews have shown the presence of antibacterial, antimicrobial, and antifungal properties in lemongrass (Mukarram *et al.* 2021; Chaudhari *et al.* 2012; Ahmad & Viljoen 2015). Therefore, the reported methods of use for lemongrass among Moroccans for health purposes are safe. More structured medical guidance on how to utilize lemongrass in a variety of languages reaching the average citizen at home is needed to maximize the medicinal benefits of the plant.

Beyond medicinal and culinary applications, lemongrass serves multiple functions globally that warrant investigation in the Moroccan context. In various countries, lemongrass is used as a mosquito repellent (Bussmann & Ajjoun 2024), in livestock treatment (particularly for blackleg) (Bussmann & Ajjoun 2024), and as a soil conservation measure on steep lands (Bussmann

& Ajjoun, 2024). Studies have demonstrated that Cymbopogon residue used as cattle feed can increase milk production by 23% (Bussmann & Ajjoun, 2024). While the present study documented some household uses such as insect repellent, future research should explore whether Northern Moroccan agricultural communities utilize lemongrass for veterinary or soil conservation purposes, as these applications could have significant economic implications for rural development.

Several studies compared the effects of lemongrass oil with other essential oils on the ability to inhibit microbial activity, citing the effectiveness of lemongrass over other choices such as garlic (Mukarram *et al.* 2021; Ganjewala & Luthra 2010; Skaria *et al.* 2006; Yadav *et al.* 2019). The lemongrass is effective in minimizing the negative effects of *Listeria monocytogenes*, *Yersinia*, *Escherichia coli*, *Staphylococcus*, *Salmonella typhimurium*, *Lactiplantibacillus plantarum*, *Pseudomonas aeruginosa, Bacillus cereus*, *Proteus vulgaris*, *Bacillus subtilis*, *Enterococcus faecalis*, and *Enterobacter aerogenes*, as elaborated from various studies (Mukarram *et al.* 2021; Abdelfattah *et al.* 2024; Singh *et al.* 2011).

This study documented a variety of ways lemongrass is integrated into the local cuisine, as well as dietary choices of Moroccans living in the Northern part of the country. All the mixtures, blends, and infusions appear to be medically safe. Participants mix lemongrass with other herbs, organic drinks, and traditional meals. Such mixtures are similar to other cultures in Africa, as well as Asia (Abiodun *et al.* 2012; Nambiar & Matela,2012). One noteworthy caution is that lemongrass still have side effects when consumed while taking certain drugs or medications. None of the studies reviewed in the literature featured citizens' awareness public health material informing consumers when to avoid lemongrass. Thus, public health agencies and non-for-profit organizations interested in herbal and traditional medicine need to develop such educational material in accessible language to reach consumers.

The essential oil from *Cymbopogon citratus* is predominantly composed of oxygenated monoterpenes with citral primarily occurring in the form of two isomers: the isomers geranial (34.47%) and neral (28.96%) which constitute a significant proportion of the volatile constituents. Research has demonstrated that lemongrass possesses excellent antimicrobial and antifungal features as well as notable anti-inflammatory and antioxidant activity attributed to its principal constituent, citral which justifies its extensive utilization in traditional Moroccan medicine (Mukarram *et al.* 2021; Mrabet *et al.* 2024). α-myrcene is present at a concentration of 18.80% along with other essential components in this analysis which exhibits anti-inflammatory, analgesic, and sedative effects that establish the plant's value for medical purposes for pain relief and anxiolytic applications (Dawood *et al.* 2022; Surendran *et al.* 2021). Lemongrass contains a synergistic combination of bioactive compounds, including geraniol (5.00%) and citronellal (0.51%) together with caryophyllene oxide (1.2%) which contribute to its antiseptic and calming properties enhancing its traditional medicinal applications for the treatment of digestive disorders, infections, and neurological conditions (Chen & Viljoen,2022). The essential oil profile identified in this study aligns with documented compositions from other regions, which consistently report α-pinene, β-pinene, β-caryophyllene, citronellal, geranyl acetate, myrcene, geraniol, limonene, nerol, terpinolene, terpinol, methylheptenone, borneol, and linalyl acetate as characteristic constituents (Bussmann & Ajjoun,2024).

The ethnobotanical survey of northern Morocco indicate that lemongrass is primarily utilized for two main purposes: culinary and medicinal applications as it is commonly consumed as an infusion to treat digestive problems as well as anxiety, stress and insomnia conditions which is aligns with its known pharmacological activities. Scientific studies corroborate the traditional use of lemongrass for gastrointestinal health application as its high citral content has been demonstrated to enhance digestion and relieve gastrointestinal discomfort (Hasan-Al-Sharif *et al.* 2023; Nishijima *et al.* 2014). The significant presence of α-myrcene in lemongrass supports its traditional use for stress management and muscle pain relief since it functions as both a sedative and muscle-relaxant monoterpene (Dawood *et al.* 2022; Surendran *et al.* 2021). The scarcity of essential oil preparations indicate that the Moroccan population mainly prefers hot-water extractions (infusions) which may be optimal for extracting water-soluble and volatile bioactive compounds while maintaining safety and ease of preparation. The majority of participants recognized the medicinal properties of lemongrass as its most significant attribute surpassing its culinary, cosmetic, and recreational uses. Traditional Moroccan knowledge about lemongrass relies on observed empirical evidence that matches with scientific findings attributed to its bioactive essential oil constituents (Haque *et al.* 2018; Olorunnisola *et al.* 2014; Wifek *et al.* 2016). The therapeutic potential of *Cymbopogon citratus* is further enhanced by its minor constituents such as geranyl formate (1.83%) and d-limonene (1.24%) that strengthen its antimicrobial and antioxidant properties for treating infections and inflammatory conditions. The broad medicinal applications of *Cymbopogon citratus* in Morocco are substantiated by its chemical profile which reveals effective medicinal properties between traditional practices and contemporary phytochemistry research.

An important consideration for future ethnobotanical research in Northern Morocco is the taxonomic distinction between *Cymbopogon citratus* (the commonly cultivated lemongrass) and *Cymbopogon schoenanthus* (the native North African species). While this study focused on *C. citratus* due to its prevalence among participants, *C. schoenanthus* presents different morphological features, including shorter, more compact growth (20–120 cm versus up to 2 m for *C. citratus*) and distinct essential oil composition (Bussmann & Ajjoun 2024). Local populations may not distinguish between these species, and it remains unclear whether *C. schoenanthus* is utilized in traditional practices or if it has been completely replaced by the introduced *C. citratus*. This question merits dedicated investigation, as native species may offer advantages in terms of climate adaptation, drought tolerance, and integration with local ecosystems.

Conclusion

To a large extent, Moroccans use of *Cymbopogon citratus* is similar to other cultural uses reported in Africa and Asia. The chemical composition of *Cymbopogon citratus* aligns closely with its traditional uses in Morocco, providing scientific validation for its widespread application in folk medicine. More importantly, participants shared new insights on how they utilize Lemongrass, which could be commercialized benefiting the local economy, as well as traditional medicine. The research paves the way for future analysis investigating the comparative use of Lemongrass across the globe to generate empirically validated findings that benefit policymakers and scientists interested in developing affordable organic therapies for common cold and the flu.

Declarations

List of abbreviations: GC-MS, gas chromatography–mass spectrometry; EO, essential oilRI, retention index; %RA, percentage of relative abundance; FAO, Food and Agriculture Organization; WHO, World Health Organization; UV, ultraviolet; v/v, volume per volume; ppm, parts per million; °C, degree Celsius; RH, relative humidity; DNA, deoxyribonucleic acid; NMR, nuclear magnetic resonance; DMSO, dimethyl sulfoxide; ANOVA, analysis of variance; SPSS, Statistical Package for the Social Sciences; n, sample size

Ethics approval and consent to participate: All participants were informed of the study's purpose, and verbal prior informed consent was obtained. This complies with the Nagoya Protocol on Access and Benefit Sharing. Data collection respected confidentiality and ethical standards.

Consent for publication: Not applicable

Availability of data and materials: All data are included in the manuscript and available from the corresponding author upon request.

Competing interests: The authors declare that they have no competing interests

Funding: Not applicable

Author contributions: J.M. collected the ethnobotanical data, performed plant material collection and essential oil extraction, analyzed the GC–MS results, and wrote the initial version of the text. M.A. participated in the theoretical background, supported questionnaire development and data interpretation, helped with discussions, and contributed to revising the text. R.W.B. supervised the ethnobotanical component of the study, validated traditional use interpretations and taxonomic information and revised the final version of the text. M.K. supervised the experimental work, validated the GC–MS analysis and interpretation, assisted with laboratory resources, and approved the final version of the text.

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