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(Research Article)

Essential oil extraction from lemongrass using steam and hydro distillation from a locally fabricated extractor

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Abstract

This study compares the chemical composition of lemongrass essential oil extracted through two distillation methods: steam distillation and hydrodistillation, using Gas Chromatography-Mass Spectrometry (GC-MS) analysis. The results reveal significant differences in the relative abundance and types of compounds present in the oils obtained by each method. Hydrodistillation yielded a higher concentration of Geranial Citral (43.50%), the primary lemon-scented component, compared to steam distillation (20.24%), making it more suitable for applications in perfumery and aromatherapy where a natural lemon fragrance is desired. Conversely, steam-distilled oil contained higher levels of trans-Carveol (35.22%), contributing a minty and herbal aroma, and was characterized by the presence of cyclic hydrocarbons such as tricyclo[2.2.1.0(2,6)]heptane, which were absent in the hydrodistilled oil. Hydrodistillation also preserved more heat-sensitive compounds and avoided the formation of synthetic artifacts seen in steam-distilled oil, which exhibited trace amounts of synthetic by-products potentially caused by the higher extraction temperature. Hydrodistillation was found to produce a purer, more aromatic oil, while steam distillation provided a broader spectrum of compounds, including cyclic hydrocarbons and heavier components. This comparison highlights how distillation techniques can significantly influence the chemical profile and potential applications of essential oils in industries such as cosmetics, perfumery, and pharmaceuticals.

Keywords: Essential oil; Lemongrass; Steam distillation; Hydro distillation; GCMS; Extractor

1. Introduction

Essential oils are natural aromatic compounds derived from various parts of plants, including leaves, flowers, and roots [2]. One such plant is Cymbopogon, commonly known lemongrass, which belongs to the grass family and is native to Africa, Asia, and tropical islands [1]. Some species, particularly Cymbopogon citratus, are widely cultivated for their medicinal and culinary uses due to their distinct lemon-like fragrance [3], similar to that of citrus fruits such as Citrus limon [4]. The method of extraction plays a crucial role in determining the quality and yield of essential oils. Among the various extraction techniques, steam distillation and hydro distillation are the most widely used. Both methods rely on heat to release volatile compounds from plant materials, but they differ in operational procedures and energy consumption. Steam distillation, a widely employed technique, leverages the volatility of the oil compounds and the steam's ability to vaporize and condense them. This method is favored for producing high-quality essential oils with minimal thermal degradation, as the plant material does not come into direct contact with boiling water [5]. In contrast, hydro distillation involves submerging the plant material directly in water and heating it to release the essential oil. While steam distillation is commonly preferred for its efficiency and the production of higher-quality oils, hydro distillation offers simplicity and cost efficiency [6]. The choice between these two methods may depend on factors such as plant material, desired oil composition, and the intended applications of the extracted oil [7].

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Gas Chromatography-Mass Spectrometry (GC-MS) is a widely used analytical technique for the characterization and identification of essential oil components. GC-MS combines the separation capabilities of gas chromatography (GC) with the detection and identification power of mass spectrometry (MS), making it ideal for analyzing the complex mixtures present in essential oils. During analysis, volatile compounds are separated based on their retention times as they pass through the GC column, and each compound is then ionized and identified by its unique mass spectrum in the MS detector. This technique provides detailed information about the composition, concentration, and purity of essential oils, allowing for the identification of major and minor constituents, including terpenes, aldehydes, and alcohols [8], [9]. GC-MS is crucial for quality control, authentication, and assessing the therapeutic or aromatic properties of essential oils [10]. The objective of this study is to compare the performance of steam distillation and hydrodistillation for essential oil extraction from lemongrass using a locally fabricated extractor. The use of locally made equipment offers a sustainable and economically viable solution for communities in developing regions, promoting the local production of essential oils without the need for expensive imported machinery.

2. Methodology

2.1. Plant Material

Fresh lemongrass leaves (Cymbopogon citratus) were harvested from Kaduna Polytechnic Tudun Wada Main Campus. The leaves were air-dried in a shaded area for 5 days to reduce moisture content without losing essential oil quality. The dried plant material was cut into small pieces to facilitate efficient extraction.

2.2. Locally Fabricated Extractor

A locally fabricated distillation unit was designed and constructed for the extraction process. The extractor as depicted in Figure 1 consists of a boiler that generates steam for the process, distillation chamber which holds the lemongrass plant material, a condenser for cooling the steam and condenses the oil and a receiver for the collection of the essential oil and water mixture for subsequent separation.

2.3. Extraction Methods

Steam Distillation

Steam distillation was conducted by generating steam at the bottom part of the extractor which is passed through the chamber containing the lemongrass leaves at the upper part of the extractor. The heat from the steam vaporized the volatile oils, which were carried along with the steam through a condenser. The condensed liquid (a mixture of oil and water) was collected, and the oil was separated by decantation. The process was carried out for three (3) hours per batch, ensuring consistent temperature and steam flow.

Hydro Distillation

Figure 1 Essential oil extractor

In hydro distillation, the lemongrass plant material was submerged in water within the boiler. The water was heated to produce steam, which carried the essential oils through the condenser. As with steam distillation, the oil-water mixture was collected and separated by decantation. The hydro distillation process was also conducted for three (3) hours per batch.

Oil Separation and Yield Calculation

After condensation, the essential oil was separated from the water using a separatory funnel. The yield of essential oil was calculated using the Equation (1):

$$\text{Yield}(\%) = \left(\frac{\text{Weight of extracted oil (g)}}{\text{Weight of lemongrass used (g)}}\right) \times 100 \quad \text{.................(1)}$$

Quality Analysis: Gas Chromatography-Mass Spectrometry (GC-MS)

The composition of the extracted oils was analyzed using GC-MS. This analysis provided detailed information on the chemical constituents of the oil, with a focus on citral content, which is the primary compound in lemongrass essential oil. The results from both extraction methods were compared to evaluate the quality of the oil produced.

3. Results and discussion

3.1. Essential Oil Yield

The results showed that steam distillation yielded a higher amount of essential oil compared to hydro distillation. On average, the steam distillation process resulted in an oil yield of 0.76 %, while hydro distillation yielded 0.44 %. The higher yield in steam distillation can be attributed to the more efficient volatilization of oils at higher temperatures with less risk of oil degradation.

3.2. Essential Oil Composition

The GC-MS of the lemon grass oil extracted through the steam distillation method and detailed composition of the oil components is given in Table 1.

Table 1 GCMS Analysis of Lemongrass Oil Extracted through Steam Distillation

S/N	RT (min)	Compound Name	Area%	Description
1	9.413	Tricyclo[2.2.1.0(2,6)]heptane, 1,3,3-trimethyl-	3.65	Found in essential oils, used as a fragrance and flavor agent.
2	14.740	Isoneral	2.16	Citrus-like scent, used in perfumery and flavor applications.
3	15.230	3,6-Octadienal, 3,7-dimethyl- (Isogeranial)	2.78	Known for lemon-like scent, commonly used in fragrances.
4	16.927	trans-Carveol	35.22	Contributes a minty, herbal aroma; used in flavorings and perfumes.
5	17.341	2,6-Octadienal, 3,7-dimethyl- (Geranial Citral)	20.24	Lemon-scented, common in essential oils, widely used in perfumery.
6	17.731	1-Cyclohexene-1-carboxaldehyde, 2,6,6-trimethyl-	3.32	Often found in plant oils, used in fragrance and flavor industries.
7	20.275	Ethanol, 2-(3,3-dimethylcyclohexylidene)-, (Z)-	1.59	Used as an intermediate in chemical synthesis.
8	44.931	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.35	Found in fats and oils, used in cosmetics and pharmaceuticals.

9	45.046	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.80	Similar to the above; used as a lipid or surfactant in formulations.
10	45.074	Furan, 2-(diphenylamino)-4-(morpholinocarbonyl)-5-(p-nitrophenyl)-	0.20	Synthetic organic compound, used in research or material science.
11	45.398	Hexadecanoic acid, 2-[(1-oxotetradecyl)oxy]-1,3-propanediyl ester	2.56	Found in fats, used in emulsifiers and cosmetics.
12	45.467	10-Nitro-3,8,13,18-tetraethyl-2,7,12,17-tetramethyl-21H,23H-porphine	0.32	Possibly a synthetic compound, could be used in dyes or research.
13	45.619	2-naphthalenecarboxamide, N,N-didecyl-1-hydroxy-	0.97	Used in industrial applications, possibly in dyes or coatings.
14	45.729	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.63	Common in skincare and cosmetic formulations as an emollient.
15	45.765	benzamide, N-[4-[[[4-(diethylamino)-2-methylphenyl]imino]methyl]-4,5-dihydro-5-oxo-1-phenyl-1H-pyrazol-3-yl]-	0.15	Synthetic organic compound, could be used in research.
16	45.865	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.66	Used in formulations for its emollient properties.
17	46.033	2-naphthalenecarboxamide, N,N-didecyl-1-hydroxy-	1.33	Industrial chemical, potential applications in materials.
18	46.077	10-Nitro-3,8,13,18-tetraethyl-2,7,12,17-tetramethyl-21H,23H-porphine	0.40	Synthetic compound, likely used in dye or material science research.
19	46.205	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.79	Similar to others; common in cosmetic and pharmaceutical formulations.
20	46.272	Furan, 2-(diphenylamino)-4-(morpholinocarbonyl)-5-(p-nitrophenyl)-	0.55	Synthetic compound, used in material research.
21	46.358	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.72	Another fatty acid ester, used in emollients and cosmetics.

Table 1 summarizes the major peaks and their corresponding compounds, along with potential applications based on the identified chemicals. The description provides context on their possible roles in industrial or commercial applications.

Table 2 GCMS Analysis of Lemongrass Oil Extracted through Hydro Distillation

S/No.	**RT (min)**	**Compound Name**	**Area %**	**Description**
1	9.412	Bicyclo[4.3.0]nonane, 2-methylene-, cis-	2.82	Organic compound contributing to complex hydrocarbon mixtures; likely a structural component in the oil.
2	14.738	Isoneral	1.82	Similar to Citral; contributes a citrus scent, potentially used for flavoring and fragrance.
3	15.233	3,6-Octadienal, 3,7-dimethyl-	2.59	Likely an isomer of citral, providing lemony fragrance.

4	16.934	trans-Verbenol	37.53	Oxygenated monoterpene with pine-like and floral fragrance, used in essential oils for therapeutic properties.
5	17.349	2,6-Octadienal, 3,7-dimethyl-(Z) (Geranial Citral)	43.50	Major component in lemongrass oil, contributing a strong lemony fragrance; used extensively in flavoring, perfumes, and cosmetics.
6	17.739	1-Cyclohexene-1-carboxaldehyde, 2,6,6-trimethyl-	0.21	Organic aldehyde contributing to complex scent profiles in essential oils.
7	20.271	Hydrazine, 1-ethyl-1-phenyl-	1.27	Nitrogen-containing compound, primarily used in industrial applications.
8	44.020	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.17	Likely a fatty acid ester, contributing to emollient properties in cosmetics and skincare formulations.
9	45.046	2-naphthalenecarboxamide, N,N-didecyl-1-hydroxy-	2.30	Aromatic amide, likely contributing to oil stability and potential as an additive.
10	45.407	Lauric acid, 2-(hexadecyloxy)-3-(octadecyloxy)propyl ester	2.26	A fatty acid ester commonly used in skincare and cosmetic formulations for its moisturizing properties.
11	45.535	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.53	Another fatty acid ester with potential uses in industrial applications and personal care products.
12	45.562	Lauric acid, 2-(hexadecyloxy)-3-(octadecyloxy)propyl ester	0.42	Similar to previous entries; adds moisturizing and stabilizing properties in formulations.
13	45.615	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester	0.59	Fatty acid ester with potential roles in emulsification and skin-conditioning products.

Similarly, Table 2 also depicts the summary of the major peaks and their corresponding compounds, along with potential applications based on the identified chemicals. The description provides context on their possible roles in industrial or commercial applications.

3.3. Comparison of GCMS Results Based on Extraction Methods

Both tables display the GCMS analysis of lemongrass oil, but extracted via different methods -steam distillation (Table 1) and hydrodistillation (Table 2). The comparison of the major compounds in the extracted oils is given in Table 3. The composition and relative abundance of compounds vary between the two, highlighting how extraction methods influence the oil's chemical profile.

Table 3 Comparison of Major Compounds in Extracted Oils through Steam Distillation and Hydrodistillation

S/no.	Major Compound	Steam Distillation (Area %)	Hydro-distillation (Area %)	Differences
1	Geranial Citral (Lemon scent)	20.24%	43.50%	Geranial concentration is much higher in hydrodistillation, contributing significantly to the lemony scent of the oil.
2	trans-Carveol / trans-Verbenol	35.22% (Carveol)	37.53% (Verbenol)	Both compounds are oxygenated monoterpenes, but trans-Verbenol dominates in hydrodistillation,

				whereas trans-Carveol does in steam distillation.
3	Isogeranial	2.78%	2.59%	Found in both oils in similar proportions, contributing to the citrus aroma.
4	Tricyclo[2.2.1.0(2,6)]heptane	3.65%	Absent	Present only in steam-distilled oil; enhances aromatic complexity but absent in hydrodistilled oil.
5	Octadecanoic acid derivatives	Multiple derivatives, totaling ~4.50%	~4.00%	Both oils contain fatty acid esters, commonly used in skincare and cosmetics, with similar concentrations.
6	Synthetic Compounds	Present in small quantities (varied types)	Absent	Synthetic compounds, possibly artifacts from distillation or contamination, are present in steam-distilled oil but not in hydrodistilled oil.

In both methods as presented in Table 3, Geranial Citral is the most dominant compound, but its concentration is significantly higher in hydrodistillation (43.50%) compared to steam distillation (20.24%). This indicates that hydrodistillation may be more effective in preserving or extracting citral, the primary component responsible for lemongrass's lemony scent.

trans-Carveol (35.22%) is more abundant in steam distillation, contributing to the minty and herbal aromas. On the other hand, trans-Verbenol (37.53%) dominates in hydrodistillation, bringing a pine-like, floral aroma.This difference suggests that steam distillation may favor the extraction of minty/herbal components, whereas hydrodistillation enhances floral/pine-like compounds like Verbenol.

Tricyclo[2.2.1.0(2,6)]heptane is only present in steam-distilled oil (3.65%). Its absence in the hydrodistilled oil could indicate that this method breaks down or doesn't extract certain cyclic hydrocarbons as effectively, potentially due to the gentler nature of hydrodistillation.

Both extraction methods yield fatty acid esters like octadecanoic acid derivatives (around 4-5%), which are useful in cosmetics for their moisturizing properties. The concentrations are fairly consistent across both methods, implying that these heavy compounds are extracted similarly regardless of distillation type.

Synthetic organic compounds such as Furan derivatives and porphyrin-related compounds were detected in steam-distilled oil but are absent in hydrodistilled oil. This could be due to higher temperatures used in steam distillation, which might promote side reactions, degradation, or contamination that introduce these compounds into the oil.

4. Conclusions

Hydrodistillation yields oil with higher concentrations of key aromatic compounds like Geranial Citral and trans-Verbenol, making it more suitable for applications where natural, lemony, and pine-like scents are desired, such as in fragrance and aromatherapy.

Steam distillation, while extracting more cyclic and heavier hydrocarbons, also introduces synthetic artifacts and promotes the extraction of herbal and minty components like trans-Carveol, making it suitable for applications requiring stronger herbal scents.

Hydrodistillation provides a more pure and natural composition, whereas steam distillation results in a broader range of compounds.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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