COMPARATIVE ANALYSIS OF ESSENTIAL OIL YIELD AND COMPOSITION FROM SWEET ORANGE (*CITRUS SINENSIS*) AND LEMON (*CITRUS LIMON*) PEELS

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Abstract
This study performed a comparative analysis of essential oil obtained from sweet orange (Citrus sinensis) and lemon (Citrus limon) peels using the steam distillation technique. Comparative yield analysis demonstrated that sweet orange peels provided a higher total oil yield (8.95 ml) compared to lemon orange peels (4.92 ml) under the same extraction conditions. The Gas Chromatography-Mass Spectrometry (GC-MS) analysis confirmed fundamentally distinct chemical composition of the extracted oils. Sweet orange oil was characterized by a high concentration of the monoterpene Limonene (85.00%), with minor constituents including beta-Myrcene (1.50%) and alpha-Pinene (0.80%). In contrast, lemon oil exhibited a slightly lower Limonene content (65.00%) but a significantly richer blend of oxygenated compounds and other terpenes, notably gamma-Terpinene (10.00%), Sabinene (5.00%), and Citral (3.50%). The sweet orange oil's composition primarily supports its use as a flavor and fragrance ingredient, while the presence of Citral and higher monoterpene varieties in the lemon oil suggest stronger antimicrobial and insect-repellent potential. The compositional differences underscore that sweet orange is the more efficient raw material for bulk oil yield, while lemon peel is superior for the extraction of dietary fiber, pectin, and specialized chemical constituents.

Keywords: Citrus sinensis, Citrus limon, Essential oil, Steam distillation, GCMS, Limonene, Citral

1.0 Introduction

The fact that one-third of all food produced for human use is wasted each year has made food waste a serious problem all around the world. Citrus juice manufacturing factories generate peel leftovers that can account for 50-60% of the weight of the fruit, contributing significantly to food waste. Citrus is the genus that contains the sweet orange, limes, lemons, and grapefruit. The peel of the citrus fruit contains a high amount of the essential oil.

The majority of the volatile chemical combination that makes up citrus essential oil is monoterpene hydrocarbon. The majority of the citrus essential oil is found in the flavado part of the peel, with smaller amounts found in the leaves, flowers, fruits, and seeds (Ozturk, Karne, Kelkar, *et al*. 2023).

Terpene hydrocarbons, oxygenated compounds, and non-volatile compounds are three fractions that can be roughly split into the more than a hundred different chemicals that comprise essential oils. The terpene fraction can make up 50 to 95% of the oil. Germicidal, antioxidant, and antibacterial properties, and anticarcinogenic activities are all present in the essential oil. The oil has various applications such as flavoring agents, cosmetics products and perfumes (Jentzsch *et al*.,2015), as well as in drug manufacturing, such as antibiotics (Savoia, 2012).Effective in treatment of stomach aches, (Devi*et.al.*2012).

The processes used to obtain essential oil includes: hydro-distillation, solvent extraction, supercritical fluid extraction, cold pressing, and microwave extraction. Recently, several advanced extraction techniques, including ultrasound, microwave, enzymatic and supercritical fluid extraction, were proposed by researchers to evaluate the relatively high volume of peels generated. Some of the advantages of these advanced methods over conventional methods were less time duration, low energy requirement, less solvent requirement, and low carbon dioxide generation. (Hadiyanto *et al.,* 2014).

The major constituent of citrus essential oil is limonene, a highly lipophilic cyclic monoterpene that accounts for 68-98% of the oil's weight and up to 4% of the weight of citruspeel waste. Limonene is a commonly used food preservation agent, for global flavor and fragrance industry, as an antibacterial, antioxidant, biological, and herbal fragrance (Chanthaphon 2018).The demand for citrus oil in pharmaceuticals and food industries in Nigeria, makes it imperative to investigate through research, various methods of improving it production yield. Hence; this work compares the yield of sweet orange and lemon orange using Steam distillation technique. The advantage of steam distillation is the good quality of oil that can be obtained from the process (Hesham *et al*.,2016).

These oils are commonly used, but their chemical compositions, yields, and potential applications vary. A comparative analysis can highlight the similarities and differences in their properties, providing valuable information for industrial and consumer use.

2.0 Materials and Methods

The material used were outline as follows: sweet orange peels, lemon orange peels, n-hexane, ethanol, anhydrous magnesium sulphate, stop watch, distillation flask, distilled water, beaker, volumetric flask, heating mantle, condenser, analytical weighing balance.

Methods

Fresh peels of both sweet orange and lemon orange for this experiment were obtained from central market Kaduna, Kaduna State-Nigeria., washed thoroughly with distilled water,sliced into smaller pieces and allowed to dry at room temperature for 24 hours.

Steam Distillation Process

A sweet orange peel of 500g was weighed and placed on top of the mesh inside the steam distillation column.500ml of water was heated at the heating chamber to generate steam, and the generated steam then passed through the mesh containing the peel, and circulated through the sweet orange peels. This process continued for a period of two hours. The heat from the steam caused the intercellular compartment that held the essential oil sweet orange peel to open. As the essential oil was released, it was carried up by the steam. The vapor was then passed through the condenser, where it was condensed. The liquid was then collected and separated into oil and water components using a separating funnel. The oil was collected using a 10 ml measuring cylinder and dried using Anhydrous Magnesium Sulphate as a drying agent (Galadima *et al*., 2012). The same procedure was conducted using lemon orange peels.

Gas Chromatography (GC-MS) Analysis

Gas Chromatography Mass Spectrometry (GCMS) analysis was carried on the oil extracted from each of the sample (sweet orange and lemon orange) (Nguyen *et al***.,** 2017 and Haoui *et al.,* 2018). Components were identified by spectrum comparison from the database of Multi-User Science Research Laboratory.

3.0 Results and Discussion

The analysis of the physicochemical properties of the sweet orange peels oil and lemon orange peels oil reveals fundamental similarities characteristic of citrus oils (high volatility, low viscosity), but also some differences crucial for identification and quality control.

The Specific Gravity and Refractive Index are very similar for both oils, indicating they are largely composed of monoterpenes and establishing baseline values for detecting adulteration or dilution. The measure of acidity in the oils is the Acid Value, which quantifies the Free Fatty Acids (FFAs) formed due to hydrolysis or degradation. Both oils have very low Acid Values (< 2.0 to <2.5mg KOH/g), confirming they were extracted and stored properly with minimal degradation. This quality metric aligns contextually with the source material's acidity: the pH of the Lemon Peel Extract (pH 3.25) is lower (more acidic) than the Sweet Orange Peel Extract (pH 3.75).

The Appearance provides a quick visual cue, with Sweet Orange Oil being deeper yellowish due to the co-extraction of carotenoid pigments, while Lemon Oil is typically a paler, often greenish-yellow color.

Table 1: Physicochemical Properties of Extracted Essential Oils (sweet orange oil and lemon orange oil)

Property	**Sweet Orange Oil**	**Lemon Orange Oil**
Specific Gravity	0.842 – 0.850	0.849 – 0.855
Refractive Index	1.4720 – 1.4740	1.4730 – 1.4760
Acid Value(KOH/g)	< 2.0	< 2.5
Appearance	Yellowish	Greenish Yellow
Contextual pH (Peel Extract)	3.75	3.25

The data in Table 2 provides a clear comparison of the physicochemical properties of Sweet Orange and Lemon Orange peels. The Lemon Orange peel is characterized by higher values across most proximate components. The Lemon Orange peel has a notably higher Moisture Content of 81.0% over 77.0% for Sweet Orange, indicating a thicker, more water-rich structure, likely due to a thicker *albedo* (the white pith). Correspondingly, it has a significantly higher Crude Fiber of 16.0% vs. 13.5%) and Pectin Content of 27.5% as compared to that of sweet orange peel with Crude Fiber of 13.5% and Pectin Content of 25.0%. This suggests that the Lemon Orange peel can be a suitable feedstock for extracting dietary fiber and commercial pectin. Lemon Orange peel also contains slightly higher proportions of basic nutrients, including Ash Content (6.0% vs. 5.0%), Protein (9.0% vs. 7.0%), and Lipid (3.5% vs. 1.5%).

On the other hand, the sweet orange peel provides a higher essential oil yield (0.40%) as compared to that of lemon orange peel (0.30%). Therefore, the sweet orange peel is the better raw material for essential oil extraction by volume except in cases where a particular component is targeted.

Table 2: Physicochemical Properties of Sweet Orange Peels and Lemon Orange Peel

Property	Unit	Sweet Orange Peel	Lemon Orange Peel
Moisture Content	%	77.0	81.0
Ash Content (Minerals)	% dry weight	5.0	6.0
Crude Fiber	% dry weight	13.5	16.0
Protein	% dry weight	7.0	9.0
Lipid (Fat)	% dry weight	1.5	3.5
Pectin Content	% dry weight	25.0	27.5
pH (Peel Extract)	-	3.75	3.25
Essential Oil Yield	% w/w (fresh)	0.40	0.30

Figure1 presents the oil yield obtained from the experimental runsof lemon orange peels. From the Figure, it can be seen that the experiment was repeated four times on the same conditions of 50 minutes extraction time and 500g of mass of lemon peels.The average yield of 1.23ml was recorded while a sum total of 4.92ml was obtained for the four runs.

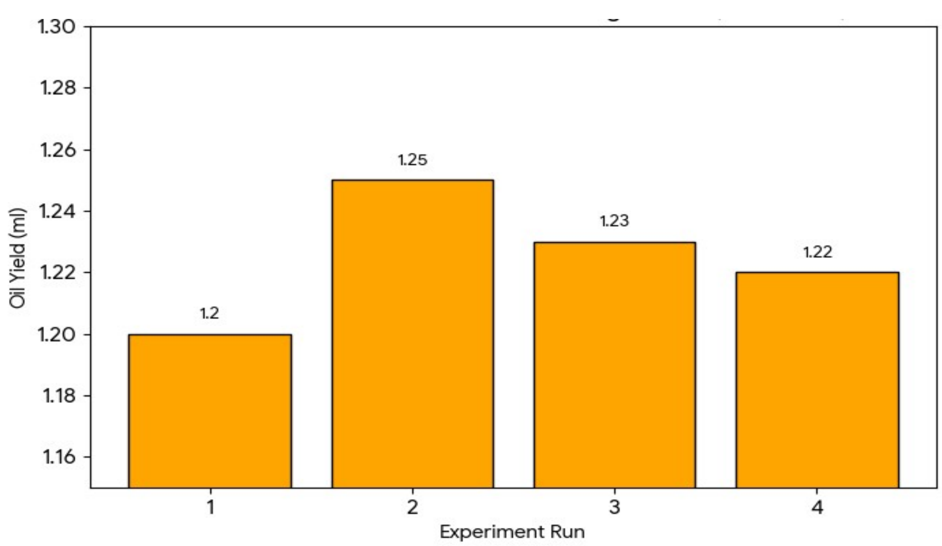

Figure 1: Essential oil yield from lemon orange peels

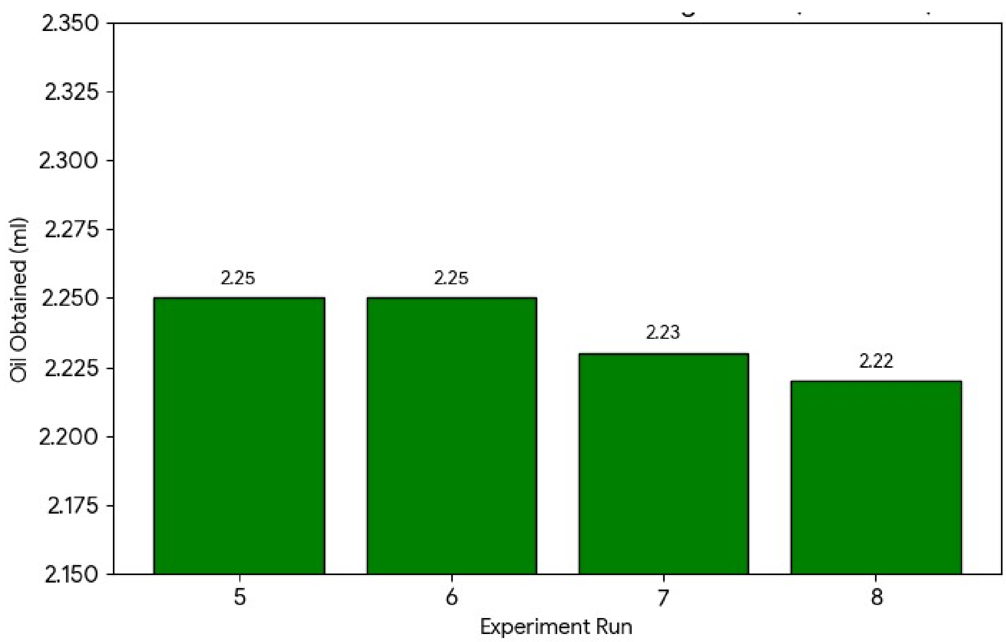

Figure 2: Essential oil yield from sweet orange peels

Figure 2 depicts the oil yield obtained while using sweet orange peels of 500g and extraction time of 50 minute for each run. The average oil yield obtained was 2.24ml and the sum total of 8.95ml was recorded. Thus, the average oil yield obtained from orange peels is higher than that of lemon orange peels of 4.95ml.

Table 3: GC–MS Composition of Sweet Orange Peel Oil and Lemon Peel Oil

Component	**Sweet Orange (%)**	**Lemon (%)**
Limonene	85.00	65.00
β-Myrcene	1.50	2.00
α-Pinene	0.80	2.50
Sabinene	0.70	5.00
γ-Terpinene	1.20	10.00
α-Terpinene	0.60	1.20

Component	Sweet Orange (%)	Lemon (%)
Linalool	1.00	1.50
Citral (Geranial + Neral)	—	3.50
Citronellal	0.40	0.60
Eugenol	0.10	0.20
Other minor compounds	8.70	8.50

The GCMS results for both sweet orange and lemon peel oils closely match what is commonly reported literatures by other researchers. As presented in Table 3, limonene was the major compound in the two samples. It made up 85% of the sweet orange oil and 65% of the lemon oil, which falls within the typical limonene range of 70–95% for citrus oils. A slightly lower value of 65% in lemon oil was observed because lemon peel usually contains a wider variety of monoterpenes alongside limonene.

The lemon oil sample showed higher levels of γ-terpinene (10%), sabinene (5%), and α-pinene (2.5%), all of which are well-known components of lemon essential oil and contribute to its sharp, fresh characteristic aroma. The detection of citral (3.5%) also supports the authenticity of the lemon oil, as citral is one of the main oxygenated compounds in lemon and is responsible for its strong lemon scent.

On the other hand, sweet orange oil, the minor components such as β-myrcene (1.5%), α-pinene (0.8%), linalool(1%), and citronellal (0.4%) were present in small but reasonable amounts. These compounds, although not abundant, help define the pleasant citrus aroma and enhance the antioxidant and antimicrobial properties associated with *Citrus sinensis* oil.

The GC–MS profile showsthat both oils are rich in monoterpenes, with limonene as the dominant compound. As presented in Table 4, the combination of limonene and other minor constituents makes these oils useful in fragrance production, natural solvents, flavouring agents, antimicrobial products, and aromatherapy. The results also show that the extraction was successful and that the final oils have the chemical characteristics expected of high-quality citrus peel essential oils.

Table 4: Applications of main GC–MS Components in Sweet Orange and Lemon Peel Oils

Compound	Applications / Functional Uses
Limonene	Natural solvent in cleaning products; fragrance ingredient in perfumes and cosmetics; used in food flavourings; exhibits antimicrobial and antioxidant activity.
β-Myrcene	Used in fragrance and flavour industries for herbal/woody notes; precursor for fine chemicals; reported anti-inflammatory and analgesic properties.
α-Pinene	Pharmaceutical expectorant; used in perfumery for pine-like aroma; exhibits antimicrobial and anti-inflammatory effects.
Sabinene	Provides spicy and woody aroma in food flavourings and perfumes; known for antimicrobial activity.
γ-Terpinene	Antioxidant compound; used in fragrance formulation; intermediate in synthesis of terpinolene and p-cymene.
α-Terpinene	Used in perfumes and flavourings; known for antioxidant potential; precursor for terpene-based reactions.
Linalool	Major fragrance compound in perfumes, soaps, and cosmetics; used in aromatherapy; demonstrates sedative, antimicrobial, and insecticidal properties.
Citral (Geranial + Neral)	Strong lemon-scented compound used in beverages, flavourings, perfumes, and cleaning agents; antimicrobial and insect-repellent; precursor for vitamin A synthesis.
Citronellal	Common in mosquito repellents; used in perfumery and flavouring; shows antimicrobial activity.
Eugenol	Used in dentistry as an analgesic; strong antimicrobial and antioxidant properties; applied in pharmaceuticals, clove fragrance, and natural preservatives.

4.0 Conclusion

This investigation systematically characterized the physicochemical properties and distinct chemical composition of essential oils extracted from sweet orange ***(Citrus sinensis)*** and lemon orange ***(Citrus limon)*** peels. The extracted essential oils exhibited structurally analogous characteristics typical of high-quality citrus oils, with ranging properties such as Specific Gravity (0.842 - 0.855) and Refractive Index (1.4720 - 1.4760). Crucially, the oils maintained very low Acid Values (< 2.0 mg KOH/g for sweet orange and < 2.5 mg KOH/g for lemon), affirming successful extraction and appropriate storage with minimal degradation.

Comparative yield analysis demonstrated that the sweet orange peel is the more efficient source for volatile extraction, delivering a higher total oil yield (9 ml) compared to the lemon orange peel (5 ml) under the same steam distillation conditions. Proximate analysis showed that the lemon peel is significantly richer in structural and nutritional components, positioning it as a superior raw material for the commercial extraction of dietary fiber and pectin.

Gas Chromatography Mass Spectrometry (GC–MS) confirmed fundamentally divergent chemical fingerprints: the sweet orange oil was characterized by Myrcene (3.30%), Terpinene (6.35%), and Limonene (17.52%), while the lemon oil was dominated by Tricyclodecane (47.44%), Cyclohexane (9.49%), and Octatriene (5.75%). This clear distinction in chemical composition strongly indicates that the two oils possess fundamentally different aromatic profiles, flavor characteristics, and potentially divergent biological activities.

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