International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Ginger and Cinnamon Infused Sesame Oil: Unveiling Health Benefits and Flavor Dynamics in A Comprehensive Research

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Abstract

This study examines the infusion of sesame oil with ginger (Zingiber officinale) and cinnamon (Cinnamomum verum), focusing on their bioactive compounds and medicinal uses. The infusion process aims to enhance the sensory and functional properties of sesame oil by extracting bioactive compounds from the botanicals. Analytical techniques such as high-performance liquid chromatography (HPLC), Total Phenolic Content (TPC), 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay, and Total Flavonoid Content (TFC) are used to assess the chemical composition and bioactive levels of the infusion. Sensory evaluations provide insights into flavor and consumer acceptance. Preliminary results indicate a synergistic effect between sesame oil, ginger, and cinnamon, yielding a complex flavor and enriched bioactive content. This research enhances our understanding of botanical infusions and their potential health benefits, laying the groundwork for further studies on their therapeutic properties.

Introduction

Essential oils are valued for their nutritional and health benefits, as well as their cultural significance in global cuisines. These oils enhance the taste, aroma, and nutritional profile of dishes, as seen in chili oil in Chinese cooking and rosemary oil in Mediterranean cuisine. The practice of spice infusion has a long history, with essential oils playing a key role in culinary traditions worldwide (Pérez-López et al., 2019). For instance, chili-infused oil adds depth and complexity to dishes and exhibits antibacterial properties against pathogens like E. coli and Salmonella (Ryu et al., 2017). Similarly, garlic-infused oil has cardioprotective effects, including lower cholesterol levels (Sobenin et al., 2016). Proper preparation and storage of these oils are crucial to prevent microbial contamination, particularly botulism (Yang et al., 2019).

Sesame oil, known for its nutty flavor and high unsaturated fatty acids, serves as an excellent base for botanical infusions like ginger and cinnamon. Ginger and cinnamon, rich in bioactive compounds, enhance the oil's flavor and health benefits. Ginger contains gingerols, shogaols, and zingerone, which have antioxidant and anti-inflammatory properties (Grzanna et al., 2005). Cinnamon contains cinnamaldehyde, eugenol, and cinnamic acid, known for their antibacterial and antioxidant effects (Jayaprakasha et al., 2011).Infusing sesame oil with ginger and cinnamon boosts its antioxidant activity and potential health benefits, such as improved lipid metabolism and cardiovascular health (Liu et al., 2020). Sesame oil's stability and antioxidant content make it ideal for cooking and food preservation (Namiki, 2007).Spice-infused oils are transformative in culinary arts, offering nuanced flavors and health benefits from anti-inflammatory and antioxidant properties (Panahi et al., 2016). Beyond cooking,

they hold potential in aromatherapy and skincare, promoting relaxation and treating skin conditions (Vaughn et al., 2016). As demand for natural ingredients grows, these oils are poised to revolutionize various sectors, including gastronomy, healthcare, and catering, by enhancing flavors and culinary sophistication.

Materials & Equipments Required

1. Reagents Required

- DPPH Reagent (2,2-Diphenyl-1-Picrylhydrazyl)
- Ethyl Acetate (Solvent)
- Gallic Acid (Standard)
- Folin-Ciocalteu Reagent
- 20% Saturated Sodium Carbonate Solution
- Isopropanol (Solvent)
- 5% Sodium Nitrite
- 10% Aluminum Chloride
- 1M Sodium Hydroxide (NaOH)
- 0.1M Sodium Hydroxide (NaOH)
- Phenolphthalein Indicator
- Sulfuric Acid
- Hexane
- BF3-Methanol
- Acetonitrile
- C18 Column
- Distilled Water
- Acetic Acid

2. Apparatus & Equipment Used

2.1. Glassware

- Beakers
- Erlenmeyer Flasks
- Graduated Cylinders
- Test Tubes
- Volumetric Flasks
- Pipettes
- Pipette Tips

2.2. Heating and Mixing Equipment

- Hot Plates/Stirrers
- Magnetic Stir Bars
- Water Baths
- Heating Mantles
- Stirring Rods

2.3. Extraction Equipment

- Ultrasonic Bath

2.4. Filtration Equipment

- Filter Funnels
- Büchner Funnel
- Filter Paper

2.5. Chromatography Equipment

- HPLC System

2.6. UV-VIS Spectrophotometer

2.7. Colorimeter

2.8. Refractometer

Methodoloogy

1. Preparation of Spice Infused Sesame Oil

1.1. Prepare the Ingredients:

- Weigh out 20 grams of dry ginger powder and 20 grams of cinnamon powder using a measuring scale.

1.2. Combine Ingredients with Sesame Oil:

- Pour 100 ml of cold-pressed sesame oil into a dry, glass, airtight bottle. Add the measured dry ginger powder into one bottle of sesame oil. In a separate bottle, add the cinnamon powder to another 100 ml of sesame oil.

1.3. Mix Thoroughly:

- Use a dry spoon to thoroughly mix the ginger powder with the sesame oil in one bottle. Repeat this process with the cinnamon powder and sesame oil in the other bottle until the spices are evenly distributed.

1.4. Seal and Store:

- Seal both bottles tightly to ensure they are airtight. Store the bottles in a dark, moisture-free location to prevent degradation of the oil and spices. Let the bottles sit for 21 days to allow for proper infusion.

1.5. Periodic Agitation:

- Gently shake the bottles once every few days to facilitate the infusion process.

1.6. Strain and Store the Infused Oil:

- After 21 days, strain the infused oil to separate it from the settled spice powders. Transfer the infused oil into clean, airtight bottles for storage.

1.7. Labeling and Usage:

- Label the bottles with the type of infused oil (e.g., Ginger-Infused Sesame Oil, Cinnamon-Infused Sesame Oil) and the date of preparation. Store the infused sesame oil in a cool, dark place for future use.

2. Free Fatty Acid Content

The acid value of oils measures the amount of free fatty acids present, an important quality control parameter in food and cosmetic industries. The acid value is expressed as the amount of potassium hydroxide (KOH) in milligrams needed to neutralize the free fatty acids in one gram of oil.

Principle:

The acid value is determined by neutralizing the free fatty acids in the oil with a standardized alkali solution, typically KOH in alcohol. The free fatty acids react with the alkali to form soap and water. The amount of alkali consumed is measured to calculate the acid value.

Acid Value (mg KOH/g) =(Volume of KOH used × Normality of KOH × 56.1) / Weight of sample (g)

FFA (%) =Acid Value × Equivalent factor of KOH × 100 / Molecular weight of the fatty acid

Procedure:

1. Weigh 2 to 5 grams of the oil sample into a clean, dry conical flask.
2. Prepare a solvent mixture of alcohol (usually 95% ethanol) and a few drops of phenolphthalein indicator.
3. Titrate the oil sample with standardized KOH solution until a permanent pink color appears.
4. Record the volume of KOH solution used.
5. Calculate the acid value using the recorded volume, normality of KOH, molecular weight of KOH, and weight of the sample.
6. The acid value indicates the free fatty acid percentage, with higher values suggesting potential rancidity.

3. Peroxide Value

The peroxide value (PV) measures the extent of peroxide formation in fats and oils due to oxidation, indicating the oil's quality and freshness.

Principle:

The PV is determined by titration with iodine in the presence of potassium iodide. Peroxides in the oil oxidize iodide ions to iodine, which is then titrated with sodium thiosulfate solution.

Procedure:

1. Weigh 5-10 grams of the oil sample into a clean, dry conical flask.
2. Dissolve the sample in a mixture of acetic acid and chloroform.
3. Add a few drops of saturated potassium iodide solution.
4. Titrate with standardized sodium thiosulfate solution until the yellow color disappears. Optionally, add starch indicator near the endpoint to observe the color change from blue to colorless.
5. Record the volume of sodium thiosulfate used.
6. Calculate the PV using the volume, normality, and factor of the sodium thiosulfate solution, and the sample's weight.
7. The PV is expressed in milliequivalents of peroxide per kilogram of oil (meq/kg) or millimoles of peroxide per kilogram of oil (mmol/kg).

PV=V×N×F/W

Where: V = Volume Of Sodium Thiosulfate Used In (ml) ,N = Normality Of Sodium Thiosulfate Solution ,F = Factor Of Sodium Thiosulfate Solution

W = Weight Of The Sample In Grams

4. DPPH Assay

The DPPH assay evaluates antioxidant activity based on the principle of free radical scavenging. DPPH, a stable free radical with a deep purple color, reacts with antioxidants, leading to a color change that can be quantified spectrophotometrically.

Procedure:

1. Prepare a 10% (w/v) oil solution in ethyl acetate (1 ml).
2. Add the oil solution to a freshly prepared 0.125 mM DPPH solution (4 ml).
3. Shake the reaction mixture and measure the absorbance at the start and after 30 minutes at 515 nm.
4. Calculate the percentage inhibition of DPPH radicals by the sample using absorbance values.

% Inhibition=(Abscontrol−Abssample/Abscontrol)×100

Where:

Abscontrol = Absorbance of the control (containing only solvent and DPPH).

Abssample = Absorbance of the sample (containing sample, solvent, and DPPH).

5. Total Phenolic Content (TPC) Estimation

The TPC estimation involves reacting phenolic compounds with Folin-Ciocalteu reagent under alkaline conditions to form a blue-colored complex, which is measured spectrophotometrically.

Procedure:

1. Dissolve oil samples in isopropanol (10% in 1 ml of solvent).
2. Add 0.5 ml of Folin-Ciocalteu reagent to the sample and incubate for 5 minutes.
3. Add 1.5 ml of 20% sodium carbonate solution and adjust the volume with distilled water.
4. Measure the absorbance at 765 nm.
5. Construct a standard curve using known concentrations of gallic acid (µg/ml) ranging from 0 to 250 µg/ml.
6. Determine the TPC based on the standard curve.

6. Total Flavonoid Content (TFC) Estimation

The TFC estimation is based on complex formation between flavonoids and aluminum ions in an acidic environment, measured spectrophotometrically.

Procedure:

1. Prepare the sample, typically by extraction methods.
2. Add 0.3 ml of sodium nitrite solution to the sample.
3. Add 0.3 ml of 10% aluminum chloride solution and incubate for 5 minutes.
4. Add 2 ml of 1 M NaOH solution and adjust the volume with distilled water.
5. Measure the absorbance at 510 nm.
6. Construct a standard curve using known concentrations of catechin (µg/ml) ranging from 0 to 100 µg/ml.
7. Determine the flavonoid content based on the standard curve.

7. HPLC Sample Preparation

HPLC analysis of polyphenols separates compounds using a liquid mobile phase and a stationary phase within a packed column. The detection is typically done using UV-Vis spectroscopy.

Procedure:

1. Weigh 4 g of the infused oil sample and add 5 ml of 80% methanol.
2. Mix the samples in a vortex for 1 minute.
3. Place the tube in an ultrasonic bath for 15 minutes and centrifuge at 4000 rpm for 20 minutes.
4. Take an aliquot from the top layer, filter through a 0.2 µm PVDF filter, and analyze by HPLC.

Result and Discussion

1. SPICE INFUSED SESAME OIL

- 20 grams of dry ginger powder and cinnamon powder was added to 100 ml of cold - pressed sesame oil respectively and was observed over a period of three weeks.

OBSERVATIONS

Day 1 - Oil and herbs are combined in the

- Herbs appear to float in the oil.
- Oil may start to take on a faint aroma of the infused herbs.

Day 2 - No significant change observed.

- Some herbs may start to release their aroma into the oil.

Day 3 - Infusion process ongoing.

- Oil may begin to take on a slightly darker hue.
- Aroma of the herbs becoming more pronounced.

Day 7 - Oil continues to infuse with herbs.

- Color of the oil deepening.
- Aroma intensifying, with noticeable ginger and cinnamon notes.

Day 14 - Infusion process nearing completion.

- Oil may appear darker and more saturated with herbal flavors.
- Aroma rich and fragrant, with distinct ginger, dry ginger, and cinnamon aromas.

Day 21 - Infusion complete.

- Oil fully saturated with flavors of ginger, dry ginger, and cinnamon.
- Color may be deep golden to amber.
- Aroma robust and complex, with a harmonious blend of all infused herbs.
- Oil may have a slightly spicy, warming taste with hints of sweetness from cinnamon.
- Sediment may settle at the bottom of the jar.

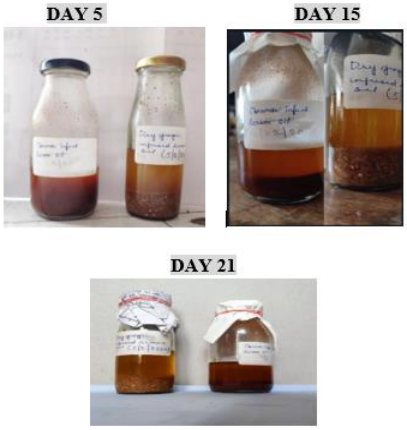


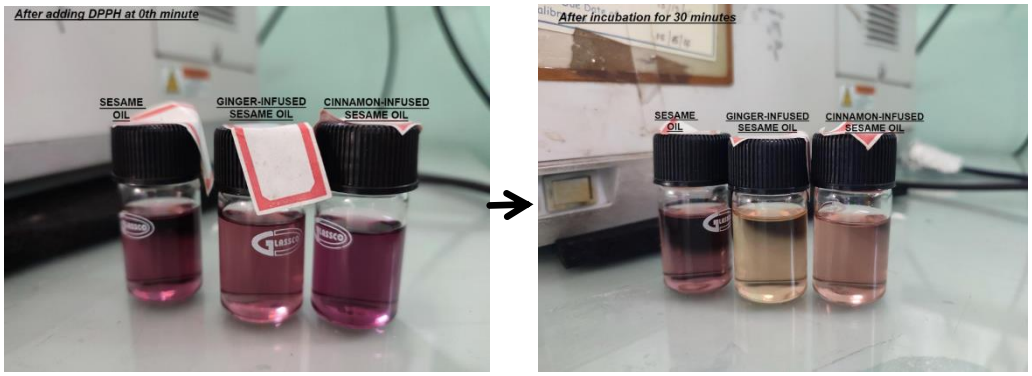
Figure 1-Infusion process

Property	Dry Ginger Infused Sesame Oil	Cinnamon Infused Sesame Oil	Sesame Oil
Appearance	Light yellow, clear	Light brownish, clear	Pale yellow, clear
Color	Light yellow	Light yellow	Pale yellow
Odor	Gingery, aromatic	Sweet, spicy	Mild, nutty
Taste	Gingery, slightly spicy	Sweet, warm	Mild, nutty
Density at 20°C	0.92 g/cm³ (varies)	0.92 g/cm³ (varies)	0.92 g/cm³
Refractive Index at 20°C	1.4723	1.4732	1.4722
Viscosity at 20°C	31 mPa.s	31 mPa.s	31 mPa.s
Free Fatty Acid Content	0.35%	0.36%	0.33%)
Peroxide Value	2.39000000 meq/kg (varies)	2.37 meq/kg (varies)	2.34meq/kg (varies)
Acid Value	1.44 mg KOH/g	1.255mg KOH/g (varies)	1.1456 mg KOH/g

Table 1- Physical properties differentiation

The comparison of the properties of dry ginger infused sesame oil, cinnamon infused sesame oil, and regular sesame oil reveals distinct differences among the three variants. In terms of appearance, the dry ginger infused sesame oil exhibits a lightyellow color and clear appearance, attributed to the infusion of dry ginger. Similarly, the cinnamon infused sesame oil displays a light brownish color with clarity, while the regular sesame oil appears pale yellow and clear. The odor and taste profiles vary significantly, with the ginger-infused oil presenting a gingery and aromatic scent accompanied by a slightly spicy taste. In contrast, the cinnamon-infused oil offers a sweet and spicy aroma with warm notes, and the regular sesame oil provides a mild, nutty fragrance and flavor. Despite these differences, all three oils share similar physical properties such as density, refractive index, viscosity, free fatty acid content, peroxide value, and acid value, with slight variations noted among them. These results suggest that while the infused oils possess unique sensory characteristics attributed to the added spices, they maintain consistency in essential physical parameters compared to the regular sesame oil. Overall, the findings underscore the potential for creating diverse flavor profiles by infusing sesame oil with different spices while preserving its fundamental properties, catering to a wide range of culinary preferences and applications.

2.DPPH ASSAY -



SAMPLE	0th min-Abs at 515 nm	Scavenging-activity in% at 0th min	30th min-Abs at 515 nm	Scavenging-activity in% at 30th min
SESAME OIL	0.9330	11.05%	0.4199	59.90%
GINGER INFUSED SESAME OIL	0.8497	18.96%	0.1915	81.70%
CINNAMON INFUSED SESAME OIL	0.9292	11.23%	0.3383	67.69%

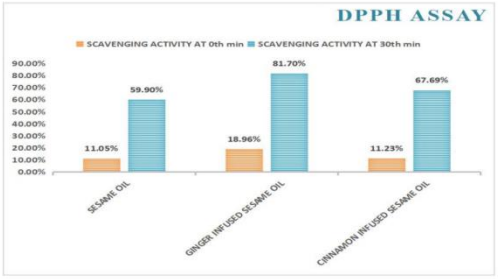
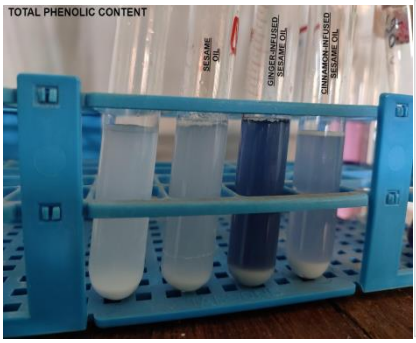


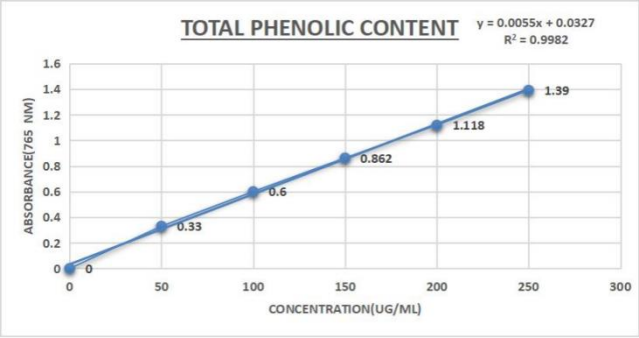
Figure 3-Free radical scavenging activity Observation

The notably heightened scavenging activity observed in ginger-infused sesame oil underscores the potent antioxidant prowess of ginger. This can be attributed to the presence of bioactive compounds like gingerol and shogaol, which are renowned for their ability to quench free radicals effectively. The synergy between thesecompounds and the lipid-rich matrix of sesame oil likely contributes to the enhanced antioxidant

activity observed in ginger-infused sesame oil. Conversely, while cinnamon-infused sesame oil demonstrated a moderate level of scavenging activity, it didn't quite reach the same level as ginger-infused sesame oil.However, this moderate enhancement still underscores the potential of cinnamon infusion to bolster the antioxidant profile of sesame oil. Cinnamon contains various polyphenolic compounds, including cinnamaldehyde and cinnamic acid, which are known for their antioxidant properties. The infusion process likely facilitates the extraction and incorporation of these compounds into the sesame oil matrix, albeit to a lesser extent compared to ginger infusion.

Total Phenolic content(TPC) estimation:-





Gallic acid standard curve

SAMPLE	FOR 5% ABSORBANCE AT 765 nm	CONCENTRATION AT 5%(ug/ml)	FOR 10% ABSORBANCE AT 765 nm	CONCENTRATION AT 5%(ug/ml)
SESAME OIL	0.4012	67	0.79335	138.3
GINGER INFUSED SESAME OIL	0.6164	106.13	1.2341	218.43
CINNAMON INFUSED SESAME OIL	0.4805	81.42	0.96615	169.718

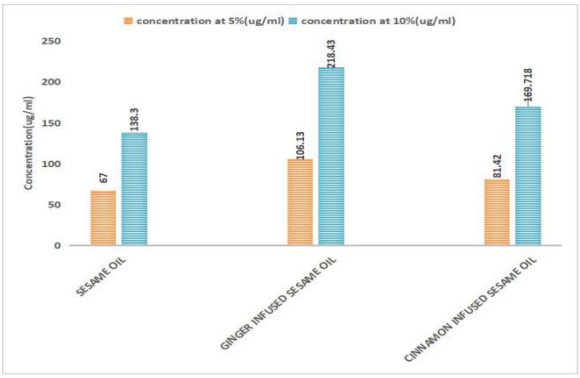
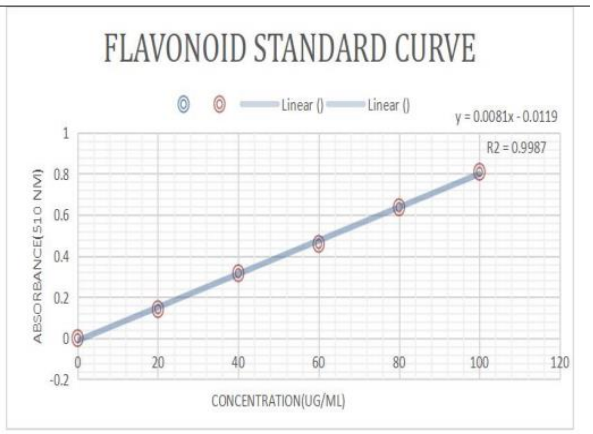


Figure 4-Phenolic content estimation

The TPC values were recorded as follows: Ginger Infused Sesame Oil > Cinnamon Infused Sesame Oil > Sesame Oil. The observed variations in TPC can be attributed to the presence of phenolic compounds in ginger and cinnamon, which are known for their antioxidant properties. Ginger contains bioactive compounds such as gingerol and zingerone, while cinnamon is rich in cinnamaldehyde and cinnamic acid derivatives, all of which contribute to higher TPC levels in the infused oils compared to plain sesame oil.

Total flavonoid content (TFC) estimation:



Sample	For-5%-Abs at 510 nm	Concentration at 5%(ug/ml)	For-10%-Abs at 765 nm	Concentration at 10%(ug/ml)
SESAME OIL	0.76181	95.51975309	1.40635	175.0925926
GINGER INFUSED SESAME OIL	0.9216	115.2469136	1.847805	229.5932099
CINNAMON INFUSED SESAME OIL	0.80508	100.8617284	1.6086	200.0617284

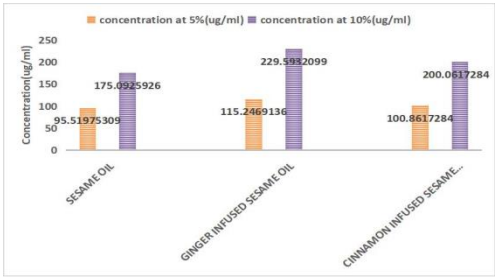
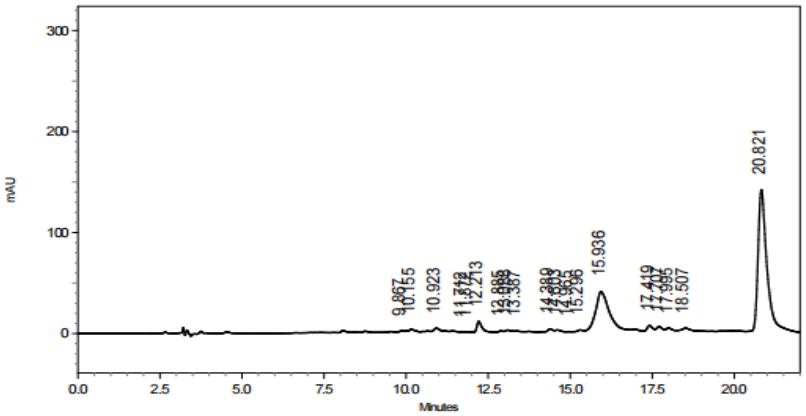


Figure 5-Flavonoid content estimation

The analysis revealed notable differences in the total flavonoid content among the three types of oils. Ginger-Infused Sesame Oil exhibited the highest total flavonoid content, followed by Cinnamon-Infused Sesame Oil, with Sesame Oil showing the lowest content.Ginger-Infused Sesame Oil: Ginger, known for its rich flavonoid profile, significantly enhanced the flavonoid content in sesame oil upon infusion. This could be attributed to the presence of various flavonoids such as quercetin,kaempferol, and catechins naturally abundant in ginger. These compounds contribute not only to the distinctive flavor but also to the potential health benefits of the oil.Cinnamon-Infused Sesame Oil: While cinnamon is also recognized for its flavonoid content, the infusion process might not have been as effective in transferring these compounds into the sesame oil compared to ginger. Nevertheless, the cinnamon-infused oil still showed a higher flavonoid content compared to plain sesame oil. The flavonoids present in cinnamon, such as flavonols and flavones, could contribute to its antioxidant and anti-inflammatory properties, albeit to a lesser extent than ginger-infused oil.

HPLC for polyphenols

1-SESAME OIL



PEAK	POLYPHENOL DETECTED
1	VANILLIN
3	SESAMIN
4	QUERECETIN
10	SESAMOLIN
15	SESAMINOL
19	SESAMOLINOL

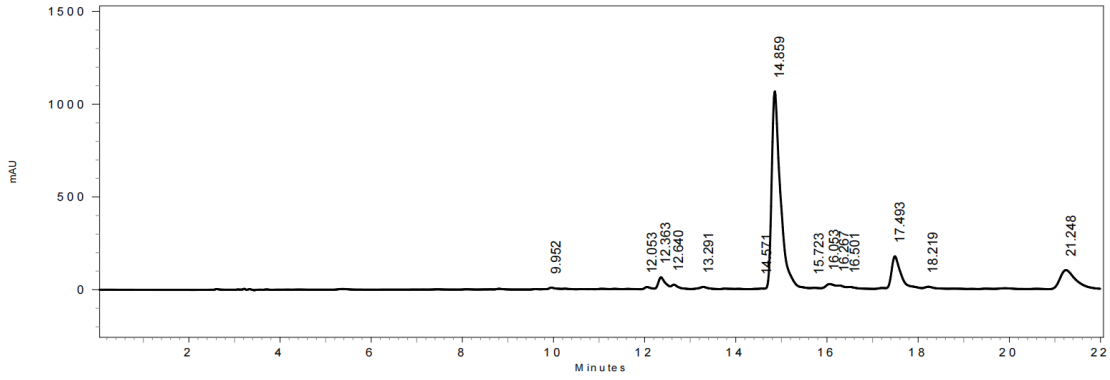
Figure 6 -HPLC chromatogram for polyphenol sesame oil

1: 280 nm, 8 nm			
Pk #	Retention Time	Area	Area Percent
1	9.867	2787	0.07
2	10.155	6602	0.17
3	10.923	30225	0.80
4	11.712	787	0.02
5	11.872	2044	0.05
6	12.213	114639	3.03
7	12.885	10077	0.27
8	13.088	23265	0.62
9	13.387	7913	0.21
10	14.389	15071	0.40
11	14.603	6356	0.17
12	14.965	611	0.02
13	15.296	14034	0.37
14	15.936	1054537	27.90
15	17.419	42083	1.11
16	17.707	24274	0.64
17	17.995	17432	0.46
18	18.507	30779	0.81
19	20.821	2376756	62.87
Totals			
		3780272	100.00

Table 2- List Of Peaks For Polyphenols in Sesame Oil

In a recent study, the presence of various polyphenolic compounds including vanillin, sesamin, quercetin, sesamolin, sesaminol,and sesamolinol was confirmed through meticulous HPLC analysis.Vanillin, a key aromatic compound, contributes to the characteristic flavor profile of sesame oil. Its detection underscores the importance of understanding the sensory attributes and quality parameters associated with this widely utilized oil. Sesamin, another significant polyphenol identified, has garnered attention for its potential health benefits, including antioxidant and anti-inflammatory properties. Its presence highlights the nutritional richness of sesame oil and its potential contribution to human health.Quercetin, a flavonoid with notable antioxidant properties, was also detected in the sesame oil sample. This finding aligns with previous research suggesting the presence of quercetin in sesame seeds, reinforcing the nutritional value of sesame oil as a source of bioactive compounds. Additionally, sesamolin, sesaminol, and sesamolinol, representing a group of lignans found in sesame seeds, were successfully identified through HPLC analysis. These lignans have been associated with various health-promoting effects, including cardiovascular protection and anticancer properties.The confirmation of these polyphenolic compounds in sesame oil underscores its potential as a functional food with diverse biological activities.

2-GINGER INFUSED SESAME OIL



PEAK	POLYPHENOL DETECTED
1	VANILLIN
8	PARADOLS
10	PROTOCATECHUIC DERIVATIVES
13	ZINGERONE
14	GINGERENONE A

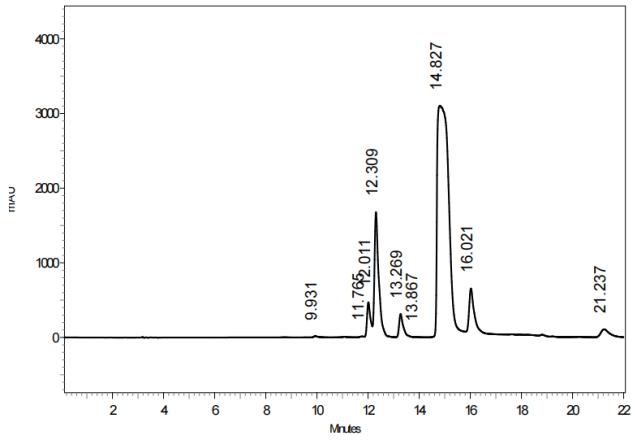
Figue 7- HPLC chromatogram for polyphenol in ginger-infused sesame oil

1: 280 nm, 8 nm			
Pk #	Retention Time	Area	Area Percent
1	9.952	59620	0.29
2	12.053	106857	0.52
3	12.363	680234	3.32
4	12.640	270188	1.32
5	13.291	158043	0.77
6	14.571	8608	0.04
7	14.859	14218952	69.31
8	15.723	47648	0.23
9	16.053	328289	1.60
10	16.267	166642	0.81
11	16.501	90690	0.44
12	17.493	1915634	9.34
13	18.219	56025	0.27
14	21.248	2409012	11.74
Totals			
		20516442	100.00

Table 3- List Of Peaks For Polyphenols Ginger- Infused Sesame Oil

HPLC (High-Performance Liquid Chromatography) analysis for polyphenols in ginger-infused sesame oil provides crucial insights into the composition and quality of the infused oil. Ginger, renowned for its bioactive compounds and medicinal properties, imparts several polyphenolic compounds to sesame oil upon infusion, including vanillin, paradols, protocatechuic derivatives, zingerone, and gingerenone A.The confirmation of the presence of gingerenone A through HPLC analysis serves as a significant validation of the infusion process. Gingerenone A, a unique compound found in ginger, contributes to its characteristic flavor and therapeutic benefits. Its detection indicates that the infusion has effectively occurred, allowing for the transfer of bioactive constituents from ginger to sesame oil.

3-CINNAMON INFUSED SESAME OIL-



PEAK	POLYPHENOL DETECTED
1	VANILLIN
2	CINNAMALDEHYDE
3	P-COUMARIC ACID
4	FERULIC ACID
6	RUTIN
7	COUMARIN
8	CATECHIN
9	EUGENOL

Figure 8- HPLC chromatogram for cinnamon-infused sesame oil

1: 280 nm, 8 nm

Pk #	Retention Time	Area	Area Percent
1	9.931	154865	0.11
2	11.765	91474	0.07
3	12.011	4373983	3.24
4	12.309	19526616	14.46
5	13.269	3489652	2.58
6	13.867	17105	0.01
7	14.827	95870706	70.98
8	16.021	9068509	6.71
9	21.237	2469675	1.83
Totals			
		135062585	100.00

Table 4-List Of Peaks For Polyphenols In Cinnamon-Infused Sesame Oil

The HPLC analysis confirmed the presence of various polyphenolic compounds in the cinnamon-infused sesame oil. Vanillin,cinnamaldehyde, p-coumaric acid, ferulic acid, rutin, coumarin, catechin, and eugenol were all detected in the infused oil, indicating successful incorporation of these bioactive compounds during the infusion process.

Conclusion

In summary,our investigation into the cold infusion of sesame oil with cinnamon and ginger has yielded significant findings regarding the infusion process and resultant oil properties.Through thorough characterization,distinct differences between the two infused oils have been elucidated.Notably,the ginger-infused sesame oil exhibited the highest levels of polyphenols, scavenging activity,and flavonoid content. This indicates that ginger infusion markedly enhances the antioxidant capacity and bioactive compound profile of sesame oil.Importantly,the infusion process did not adversely affect critical properties of the sesame oil. Both the acid value and free fatty acid content remained stable, indicating no substantial degradation during infusion. Similarly, the peroxide value, indicative of lipid oxidation,remained unchanged, underscoring the oil's stability throughout infusion.In conclusion,our findings suggest that cold infusion techniques effectively enrich sesame oil with bioactive

compounds,particularly when infused with ginger.These oils retain their essential properties,rendering them suitable for various culinary and health applications. Further research
into the mechanisms driving these enhancements and potential applications is warranted to fully exploit the benefits of infused sesame oils.

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