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Food safety and surveillance studies on the quality of traditional cold-pressed edible vegetable oils

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Abstract

This study has been conducted to investigate quality and safety of cold-pressed vegetable oils processed at cottage level industries. A total number of 75 samples of coconut, groundnut, and sesame oils collected from different districts of Tamil Nadu, analyzed to ascertain its quality and safety in compliance with the Food Safety Standard Regulations (FSSR) of FSSAI, 2011. Physico – chemical, fatty acid profile, vitamin and trace elemental analysis were carried out. Results revealed that though some of the oils samples are complied with the specification as per the standard, but on the other side 80% of the collected samples were found to fail in meeting at least for one parameter as per the requirements. Results are in deviations for the parameters such as refractive index, specific gravity, iodine value, and saponification value are also noticed and few samples are reported positive results for the presence of mineral oil and argemone oil and possibilities for adulteration. Notably, 15 samples were found to comply with the requirements for physiochemical parameters, fatty acid profiles and trace element levels which are found below permissible limits (≤0.05 mg/kg). Vitamin E was detected only in coconut oil (0.1059 to 0.1622 mg/100g). Whereas, antioxidant assay and color, remained satisfactory. Overall, the study underscores the importance of consumer awareness and adherence to established standards to ensure the integrity and safety of edible oils, highlighting the need for continued monitoring and enforcement efforts to address identified shortcomings and uphold market integrity.

Keywords: Edible cold-pressed oils, physiochemical parameters, Food Safety Standard Regulations 2011

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1. Introduction

Vegetable oils are derived mainly from plant seeds and consist mostly of triglycerides, which are esters of fatty acids. Vegetable oils primarily include lipids, or fats, and also contain small amounts of flavorings, colorants, antioxidants, and emulsifiers. Consumers prefer vegetable oils because of their superior quality, and absence of cholesterol [1-2]. Food Safety Standards Authority of India. Oils are necessary for our diet since they provide essential nutrients, including energy, omega-3, and fatty acids which our systems are unable to synthesize), and facilitate the absorption of fat-soluble vitamins A, D, E, and K [3]. Customers are exhibiting a growing tendency towards cold-pressed oils in comparison to refined oils because of the greater abundance of beneficial components produced via the pressing process. Substances including tocopherols, polyphenols, and squalene have been scientifically shown to hinder lipid oxidation and function as antioxidants. The efficacy of antioxidants is crucial for cold-pressed oils that are abundant in polyunsaturated fatty acid, which are highly prone to oxidation that leads to oil degradation and potentially harmful health consequences upon consumption [4]. There are various techniques are employed to monitor and regulate the authentic nature of cold-pressed oils, driven by the need to safeguard human health and meet consumer demand [5]. The procedure of isolating triglycerides from oilseeds is known as extraction. This can be achieved using a range of chemical, biochemical, and mechanical methods, aiming to optimize yields while preserving the product's quality with minimal alterations. Cold-pressing is a mechanical technique used to extract oil from many different types of seeds and nuts [6]. This mechanical process preserves the beneficial components of the oil, such as free fatty acids, antioxidants, and vitamins, especially fat-soluble ones like vitamins D and E, monounsaturated fatty acid, and polyunsaturated fatty acid Cold-pressing, unlike other industrial methods, operated at low temperatures, usually below 49°C. Conversely, the use of high temperatures in industrial processing might lead to the degradation of the vital constituents of the oil. This study focuses on three cold-pressed oils - coconut, groundnut, and sesame, known for their antioxidant richness and culinary significance, particularly in Tamil Nadu, India. Coconut oil, extensively utilized in both households and commercial sectors for cooking, baking, medicinal, and cosmetic purposes [7] boast a substantial content of lauric acid, ranging from 44 to 53.2%. Comprising 92% saturated fatty acids, primarily in the form of triglycerides, with around 70% being

medium-chain fatty acids, coconut oil demonstrates resistance to peroxidation [8]. Groundnut oil, oleic acid levels between 35 and 69%, alongside vital vitamins and minerals, including vitamin E, potassium, sodium, calcium, manganese, iron, and zinc, along with bioactive compounds such as arginine, resveratrol, phytosterols, and flavonoids [9]. Sesame oil, derived from a traditional crop, predominantly consists of triglycerides, with notable percentages of monounsaturated oleic acid (40%), polyunsaturated linoleic acid (45%), and approximately 10% saturated fats [10].

Locally produced cold-pressed oils lack defined quality control measures, unlike commercially processed edible oils as regulated by the Food Safety and Standards Authority of India (FSSAI). Furthermore, there are no availability of any regulatory system / standard specification to monitor the quality of desi / cottage level processed cold – pressed oil. Hence, the present research project endeavor not only to assess the safety and quality of cold-pressed oils through an examination of various factors, including physical and chemical parameters, fatty acid profiles, metal contaminants, and vitamins D_3 and E, ensuring their suitability for human consumption, but also to identify areas of concern and potentially establishing standardized specifications for cold-pressed oils with clear benchmarking limits.

2. Materials and methods

Totally 75 different samples of cold-pressed oils (coconut oil, groundnut oil, and sesame oil) were collected from five districts in Tamil Nadu, India: Chennai, Chengalpattu, Dindigul, Virudhunagar, and Thiruvallur. The collected samples were stored in polypropylene bottles at an ambient temperature of 32°C until further analysis [11].

2.1 Determination of the physical, chemical, and adulteration analysis of cold-pressed oils.

Indian Standard (IS:548 (Part 1)-1964 RA: 2010) and FSSAI Manual of method for analysis of oil fats (Revised Edition, 02.009:2021) methods [12-13] were adopted to analyze both the physical and chemical parameters of cold-pressed oils, color was measured using Lovibond Tintometer (Model FX, UK).

2.2 Determination of antioxidant by DPPH- Free radical scavenging activity

The antioxidant levels in oil samples were assessed using the 2-Diphenyl-1-Picrylhydrazyl (DPPH) method. A mixture of 20µl (10 mg) of the oil samples, 0.5 ml of methanolic DPPH solution, and 0.48 ml of methanol was prepared. This reaction solution was left undisturbed at the specified temperature for 30 min during the incubation period. Methanol was utilized as a blank to establish a baseline for the experiment. For the positive control, DPPH dissolved in methanol was used without the sample. Following the incubation period, a UV-visible spectrophotometer (ATI/Unicam UV2, UK) was employed to measure the reduction in the purple color at a wavelength of 518 nm [10].

2.3 Determination of fatty acid profile by GC-FID

Fatty acid content analysis of collected samples of coconut oil, groundnut oil, and sesame oils was conducted using the GC-FID method. A gas chromatograph equipped with a flame ionization detector (FID) from Thermo Scientific, Inc., San Jose, CA, USA, was utilized for this analysis. The analysis employed a Supelco SP-2560 capillary column measuring the length is 99.9 m, a diameter is 0.24 mm, and a thickness film of 0.19 µm. Samples were introduced into the split-splitless system of an AS 3000 autosampler in split mode, with a 1:100 ratio, at a temperature of 260 °C. The oven temperature was initiated at 140 °C for 5 min and gradually increased at a rate of 4°C per minute until it reached 240 °C, where it was held steady until the analysis was completed. The Flame Ionization Detector (FID) temperature was set at 260 °C. The fatty acid composition was achieved by comparing retention times with a reference mixture, and their relative concentrations were measured as a percentage of the total peak area. Each sample underwent three analyses. Data collection and analysis were performed using Chrom Quest 5.0 software developed by Thermo [14-15]. Their corresponding methyl esters were analyzed to determine the relative quantity of fatty acids (FAs) in the oil sample. Initially, 5-7 small droplets of the oil were added to a 15 ml test tube. Then, 3 ml of a solution containing 0.5 M sodium methoxide, prepared by mixing metallic sodium with methanol, was added. The mixture was placed in a vigorously boiling water bath and stirred continuously for about 15 minutes. After cooling to room temperature, 1 ml of petroleum ether (with a boiling point range of 40-60°C) and 10 ml of deionized water were slowly added and gently mixed. The solution was then allowed to settle undisturbed for 5-6 minutes to separate the upper layer of methyl ester in petroleum ether, which was carefully transferred to a sealed container for analysis. Furthermore, fatty acid standards in the form of methyl esters were separately dissolved in 10 ml of petroleum ether. Then, 200 mg of each standard was placed into test tubes equipped with screw covers. The gas chromatography apparatus received injections of 1 µL aliquots of fatty acid methyl esters (FAME). The system's data processing section recorded the peak retention times and areas of the fatty acids for analysis. [16].

2.4 Determination of vitamins D_3, and E in edible oil by HPLC

Vitamin D_3 and E concentrations in the collected samples were analyzed using High-Performance Liquid Chromatography (HPLC) equipped with a UV detector. The study was conducted using a state-of-the-art high-performance liquid chromatograph, especially the Series 1100/1200 type produced by Agilent Technologies in the United States. The separation of chemicals using chromatography was performed using a Gemini C18 column (100 × 3.0 mm, 3 µm particle size) manufactured by Phenomenex, a company based in the United States. The column was kept at a constant temperature of 40°C. The mobile phase, composed of acetonitrile and water at a volumetric ratio of 99:1, was delivered at a flow rate of 1 ml/min. The injection volumes varied between 3 and 50 µl, depending on the sample preparation. The measurements were conducted at a wavelength of 265 nm [17]. Methanol 98% is employed as a mobile phase, with the solvent consisting of 100 ml of methanol, 100 ml of acetonitrile, and 200 ml of isopropyl alcohol. For the separation of vitamin D_3 and vitamin E, use 24 mg of cholecalciferol and 50 mg of tocopherol. Place these amounts in two separate 50 ml flasks and add 30 ml of solvent to each flask. Sonicate the flasks for

5 min. Combine 1 ml of vitamin D_3 and 5 ml of vitamin E in a 50 ml flask, then fill the flask to the top with solvent. To prepare the sample, combine a 5 ml sample with 50 ml of solvent and subject it to sonication for 15 min to facilitate the breakdown of molecules. Next, introduce 50 µl of a solvent, standard solution, and sample solution into the chromatogram. Proceed to document the chromatograph and quantify the peak.

2.5 Analysis of metallic and trace elements by ICP-MS

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) with the Agilent Technologies Model 7850 US was employed to analyze metallic and trace elements, including Cadmium (Cd), Lead (Pb), Mercury (Hg), and Arsenic (As). Three replicate tests were conducted using a standard calibration curve. The operational settings of the ICP-MS instrument were set up as follows: The nebulizer gas flow rate was set at 1 ml/min, while the auxiliary and plasma gas flow rates were kept at 1 ml/min and 15 ml/min, respectively. The power parameters for reflection and transmission were adjusted to 45 W and 1500 W, respectively. In addition, the helium gas flow rate was maintained at 0.2 ml/min throughout the process [18]. The oil samples were first digested to solubilize the elements present. Approximately 1g of each oil sample was weighed into a digestion vessel, followed by the addition of an appropriate digestion mixture, typically a combination of nitric acid (HNO3) and hydrogen peroxide (H2O2). The samples were then heated to a controlled temperature, typically in the range of 90-120°C, to facilitate the digestion process. After complete digestion, the solutions were cooled and transferred to volumetric flasks, where they were diluted to a suitable volume with deionized water. Subsequently, the prepared samples were introduced into the ICP-MS for analysis. During analysis, the samples were nebulized and introduced into the plasma torch, where they were atomized and ionized. The resulting ions were then separated based on their mass-to-charge ratio (m/z) and detected by the mass spectrometer. Calibration curves were constructed using standard solutions of known elemental concentrations to quantify the levels of trace elements in the samples. Quality control measures, such as the analysis of blank samples and certified reference materials, were employed to ensure the accuracy and precision of the results. Detection limits for each element were determined based on signal-to-noise ratios, and data analysis was performed using dedicated software. This method provides sensitive and accurate determination of trace elements in edible oils, essential for assessing their quality and safety.

2.6 Statistical analysis

The statistical analysis was conducted using SPSS software version 17.0. All data represent the average of three separate measurements and are accompanied by the standard deviation of the mean. The analysis of variance (ANOVA) was used to compare the groups of samples, with a significance level of $p < 0.05$, to identify any significant differences between the average values.

3. Results and Discussions

3.1 Physical analysis of cold-pressed oil

The results of the physical parameters of cold-pressed coconut, groundnut, and sesame oils are presented in Table 1. For coconut oil, the refractive index ranged from 1.4485℃ to 1.4489°C, while, the refractive index of groundnut oil, ranged from 1.4630℃ to 1.4631℃, the results were well within the limits of Food Safety Standards Regulations (FSSR 2011). Whereas in the case of sesame oil, the refractive index ranged from 1.4656℃ to 1.4669°C, except for one sample as it does not meet the specification as laid down in FSSR 2011. The cloud point of coconut oil ranged from 17.98℃ to 18.26°C, whereas 4.48℃ to 4.57℃ and -7.33 ℃ to -7.36 ℃ for groundnut oil and sesame oils, respectively. The results were within the specified standard limits of FSSR 2011.The color of the all three oils are found to be within the acceptable limits as per IS 1964 (4.08 to 20.3). The visible color of coconut oil is colorless, groundnut oil is yellow and sesame oil is golden yellow. The pH ranged from 5.8 to 6.53, as a result, the coconut oil has a slightly acidic tendency, whereas the groundnut oil and sesame oil indicate an acidic nature. The moisture content of the samples (coconut, groundnut, and sesame oil) ranges from 0.02% to 0.11%; overall, coconut oil exhibited a higher moisture content, while groundnut oil had a lower moisture content, as the study conducted by [19] which show the moisture content in the soybean bean oil varied between 0.2% to 0.82%. The oil samples exhibited a variety of specific gravity values, ranging from 0.91 to 0.94, where the results were compared to FSSR (2011) standards, one sample of coconut and groundnut oil from Chengalpattu and Virudhunagar districts, as well as two samples of sesame oil from Chengalpattu and Thiruvallur districts, did not meet the FSSR 2011 specifications.

3.2 Chemical analysis of cold-pressed oils

The results of the chemical parameters of cold-pressed coconut, groundnut, and sesame oils are mentioned in Table 2. The acid values for the oil samples varied between 0.46 mg KOH/g oil and 0.89 mg KOH/g oil, which were the ranges within the permissible limits set by FSSR 2011. The acid value of oils is a measure of the amount of free fatty acids (FFA) in the oil. The FFA percentages for lauric acid in coconut oil and oleic acid in groundnut and sesame oils are evaluated which was determined by [20]. The free fatty acid content varied from 0.17% to 0.49%, below the specified standard limit of 0.3% maximum as lauric acid and oleic acid. Iodine values for coconut oil varied between 9.35 g/100g to 9.5g/100g while sesame oil ranged from 108.66 g/100g to 117.55 g/100g, the results were within the limits of FSSR 2011. Whereas in the case of groundnut oil ranges from 92.68 g/100g to 103.33 g/100g except one sample as it does not meet the specification as laid down in FSSR 2011. The peroxide test for the samples was analyzed. The oil used for frying and subjecting it to prolonged exposure to high temperatures causes a decline in the quality of the oil (rancidity), which leads to the formation of an unpleasant odor or flavor that may be toxic to human health studied by [21]. The sample's coconut, groundnut, and sesame oil, no evidence of rancidity was seen. This may be ascribed to the fact that the samples were fresh and had not undergone any processing or been kept for an extended period. Similarly, saponification values of coconut oil samples ranged from 260.24 mg KOH/g oil to 262.95 mg KOH/g oil, exceeding the FSSR 2011 limit of ≥ 250 mg KOH/g oil.

Table 1: Physical analysis of cold-pressed edible oils

Districts of Tamil Nadu	Samples	Physical parameters							
		Refractive index at 40℃	BR at 40 ℃	Cloud Point ℃	Color	Visible color	pH	Moisture % (m/m)	Specific gravity at 30℃
Chennai	Coconut oil	1.4487^{df}	34.9	18.26±0.07^{a}	4.98±0.01^{l}	Colourless	6.2±0.07^{e}	0.11±0.02^{a}	0.91^{h}
Chengalpattu		1.4489^{d}	35.1	17.98±0.06^{b}	4.49±0.01^{m}		6.09±0.01^{g}	0.05±0.01^{cde}	0.94^{a}
Dindigul		1.4487^{ef}	34.9	18.01±0.03^{b}	4.08±0.06^{k}		5.91±0.01^{h}	0.06±0.01^{cd}	0.92^{e}
Thiruvallur		1.4485^{f}	34.6	17.98±0.04^{b}	4.68±0.01^{m}		5.83±0.04^{i}	0.03±0.01^{fg}	0.92^{f}
Virudhunagar		1.4487^{def}	34.9	18±0.07^{b}	4.7±0.01^{m}		5.92±0.06^{h}	0.02±0.01^{g}	0.92^{e}
Chennai	Groundnut oil	1.463^{c}	55.6	4.57±0.03^{c}	14.88±0.01^{j}	Yellow	6.4±0.01^{d}	0.09±0.01^{ab}	0.92^{d}
Chengalpattu		1.4631^{c}	55.7	4.54±0.09^{c}	16.6±0.12^{h}		6.6±0.01^{a}	0.07±0.01^{bcd}	0.91^{i}
Dindigul		1.4633^{c}	56	4.54±0.09^{b}	17.99±0.03^{g}		6.53±0.01^{b}	0.07±0.01^{bcd}	0.92^{e}
Thiruvallur		1.4631^{c}	55.7	4.48±0.11^{d}	15.1±0.01^{i}		6.5±0.01^{b}	0.05±0.01^{cde}	0.92^{f}
Virudhunagar		1.4631^{c}	55.7	4.55±0.03^{c}	19.06±0.04^{f}	Yellow	6.47±0.01^{c}	0.04±0.01^{def}	0.93^{c}
Chennai	Sesame oil	1.4656^{b}	59.5	-7.33±0.03^{d}	19±0.01^{c}	Golden yellow	6.2±0.01^{e}	0.07±0.01^{bc}	0.92^{d}
Chengalpattu		1.4669^{a}	61.5	-7.35±0.11^{d}	20.3±0.09^{e}		6.17±0.01^{ef}	0.06±0.01^{cd}	0.93^{b}
Dindigul		1.4657^{b}	59.7	-7.34±0.07^{d}	19.12±0.06^{d}		6.12±0.01^{fg}	0.04±0.01^{def}	0.92^{f}
Thiruvallur		1.4657^{b}	59.7	-7.4±0.13^{d}	18.8±0.06^{b}		6.17±0.01^{e}	0.05±0.03^{cde}	0.93^{c}
Virudhunagar		1.4656^{b}	59.5	-7.36±0.07^{d}	18.13±0.01^{a}		6.12±0.01^{fg}	0.05±0.03^{cde}	0.92^{c}

Values are presented as means ± standard deviation of triplicates. Columns bearing dissimilar superscripts, statistically significant differences *($p < 0.05$)*. BR- Butyro refractive index.

Table 2: Chemical analysis of cold-pressed edible oils

Districts of Tamil Nadu	Samples	Chemical parameters							
		Acid value (mg KOH/g oil)	**Free fatty acid % (m/m)**	**Iodine value (g/100g)**	**Peroxide value (meqO_2/kg oil)**	**Saponification Value (mg KOH/g oil)**	**Unsaponifiable matter % (g/kg)**	**Polenske value °C**	**DPPH %**
Chennai	Coconut oil	0.63±0.01^{a}	0.17±0.01^{f}	9.5±0.01^{g}	Not Detected	262.2±0.36^{a}	0.7±0.01^{cd}	15.42±0.09^{c}	44.37±0.1^{f}
Chengalpattu		0.61±0.01^{a}	0.18±0.01^{ef}	9.35±0.09^{g}		261.33±0.14^{b}	0.46±0.01^{gh}	15.12±0.06^{d}	49.74±0.52^{e}
Dindigul		0.62±0.01^{a}	0.19±0.01^{e}	9.35±0.09^{g}		262.25±0.32^{a}	0.6±0.06^{def}	15±0.15^{d}	30.68±0.41^{j}
Thiruvallur		0.62±0.02^{a}	0.19±0.01^{e}	9.35±0.08^{g}		260.24±0.75^{c}	0.61±0.01^{def}	16.02±0.31^{a}	25.2±0.01^{n}
Virudhunagar		0.62±0.03^{a}	0.19±0.01^{e}	9.35±0.09^{g}		262.95±1.04^{a}	0.58±0.03^{ef}	15.73±0.03^{b}	56.37±0.1^{b}
Chennai	Groundnut oil	0.46±0.01^{b}	0.23±0.01^{a}	92.68±0.01^{f}	Not Detected	193.56±0.22^{e}	0.73±0.01^{c}	Not Applicable	26.39±0.02^{m}
Chengalpattu		0.47±0.01^{b}	0.24±0.01^{a}	92.77±0.03^{f}		193.58±0.1^{e}	0.37±0.03^{i}		27.34±0.26^{l}
Dindigul		0.46±0.01^{b}	0.23±0.01^{a}	92.77±0.03^{f}		193.52±0.21^{e}	0.73±0.01^{c}		29.41±0.12^{k}
Thiruvallur		0.47±0.01^{b}	0.24±0.01^{a}	99.82±0.11^{e}		193.57±0.22^{e}	0.51±0.02^{fg}		24.5±0.04^{o}
Virudhunagar		0.47±0.01^{b}	0.24±0.01^{a}	103.33±0.39^{g}		193.5±0.19^{e}	0.64±0.08^{cde}		35.66±0.13^{i}
Chennai	Sesame oil	0.89±0.01^{c}	0.45±0.01^{cd}	108.66±0.21^{c}	Not Detected	227.08±0.19^{d}	1.38±0.01^{a}	Not Applicable	53.35±0.17^{c}
Chengalpattu		0.88±0.01^{c}	0.45±0.01^{cd}	116.68±0.66^{b}		192.93±0.01^{e}	1.37±0.01^{a}		50.84±0.11^{d}
Dindigul		0.88±0.01^{c}	0.46±0.01.^{c}	116.68±0.66^{b}		227.08±0.21^{d}	1.13±0.09^{b}		40.78±0.11^{h}
Thiruvallur		0.89±0.01^{c}	0.36±0.01^{e}	117.55±0.45^{a}		226.22±0.47^{d}	1.38±0.01^{a}		42.62±0.02^{g}
Virudhunagar		0.88±0.01^{c}	0.49±0.01^{b}	116.68±0.66^{b}		226.56±1.14^{d}	0.61±0.16^{def}		59.47±0.01^{a}

Values are presented as means ± standard deviation of triplicates. Columns bearing dissimilar superscripts, statistically significant differences *($p < 0.05$)*

Table 3: Adulteration analysis of cold-pressed edible oil

Districts of Tamil Nadu	Samples	Adulteration checks		
		Test for argemone oil	Test for mineral oil	Bellier test °C
Chennai	Coconut oil	Negative	Negative	Not Applicable
Chengalpattu			Positive	
Dindigul				
Thiruvallur				
Virudhunagar				
Chennai	Groundnut oil	Negative	Negative	38.72±0.61[b]
Chengalpattu				39.07±0.1[a]
Dindigul			Positive	39.03±0.09[ab]
Thiruvallur		Positive		38.74±0.2[b]
Virudhunagar				39.16±0.04[a]
Chennai	Sesame oil	Negative	Negative	16.76±0.05[e]
Chengalpattu				17.4±0.14[d]
Dindigul			Positive	18.9±0.13[c]
Thiruvallur		Positive		17±0.08[e]
Virudhunagar				17.04±0.09[e]

Values are presented as means ± standard deviation of triplicates. Columns bearing dissimilar superscripts, statistically significant differences ($p < 0.05$).

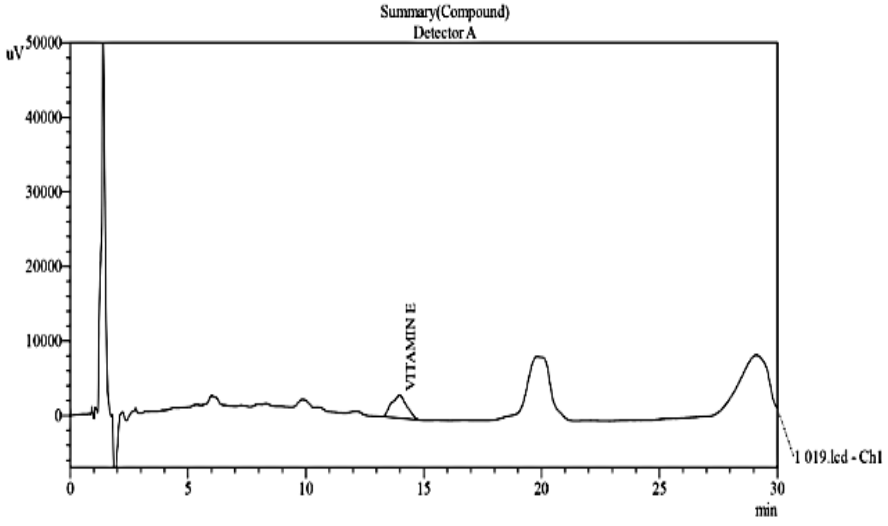

Fig. 1 The HPLC-UV detector chromatogram of vitamin E presence in coconut oil

Table 4: Fatty acid profile of cold-press edible oils

S.no	Fatty acid profile (g/100g)	Districts of Tamil Nadu				
		Chennai			Chengalpattu	
		Coconut oil	Groundnut oil	Sesame oil	Groundnut oil	Sesame oil
1		**Saturated fatty acid**				
1a	C6:0 Caproic Acid	0.39 ± 0.03	<0.10	<0.10	<0.10	<0.10
1b	C8:0 Caprylic Acid	6.6 ± 0.21	<0.10	<0.10	<0.10	<0.10
1c	C10:0 Capric Acid	4.98 ± 0.09	<0.10	<0.10	<0.10	<0.10
1d	C12:0 Lauric Acid	45.63 ± 0.44	0.91 ± 0.04	<0.10	0.93	<0.10
1e	C14:0 Myristic Acid	20.49 ± 0.41	0.45 ± 0.03	<0.10	0.49	<0.10
1f	C16:0 Palmitic Acid	9.45 ± 0.14	14.07 ± 0.05	10.05 ± 0.04	10.99	10.17
1g	C18:0 Stearic Acid	3.40 ± 0.25	3.80 ± 0.16	6.89 ± 0.08	3.98	6.98
1h	C20:0 Arachidic Acid	<0.10	1.63 ± 0.45	0.73 ± 0.06	1.04	0.87
1i	C22:0 Behenic Acid	<0.10	2.98 ± 0.22	0.26 ± 0.04	2.88	0.44
1j	C24:0 Lignoceric Acid	<0.10	1.02 ± 0.14	0.16 ± 0.04	0.85	0.19
2		**Mono-unsaturated fatty acid**				
2a	C16:0 Palmitoleic Acid	<0.10	<0.10	0.16 ± 0.02	<0.10	0.18
2b	C18:1 Oleic Acid	6.41 ± 0.64	39.9 ± 0.55	43.04 ± 0.05	41.95	42.87
2c	C20:1 cis-11-Eicosenoic Acid	<0.10	0.91 ± 0.07	0.18 ± 0.01	0.95	0.26
3		**Trans fatty acid**				
3a	Elaidic Acid	<0.10	<0.10	<0.10	<0.10	<0.10
3b	Linolelaidic Acid	<0.10	<0.10	<0.10	<0.10	<0.10
4		**Polyunsaturated fatty acid**				
4a	C18:2 Linoleic Acid	2.42 ± 0.80	33.65 ± 0.59	38.03 ± 0.13	34.85	37.56
4b	C18:3 alpha-Linolenic Acid	<0.10	<0.10	0.35 ± 0.60	<0.10	0.42
	Saturated fatty acid	90.96	25.02	18.10	21.66	18.65
	Mono-unsaturated fatty acid	6.41	40.81	43.39	42.9	43.31
	Trans fatty acid	<0.10	<0.10	<0.10	<0.10	<0.10
	Polyunsaturated fatty acid	2.42	33.65	38.38	34.85	37.98

Whereas, groundnut and sesame oil ranged from 193.52 mg KOH/g oil to 227.08 mg KOH/g oil. As a result in comparison with FSSR (2011) standards, four samples of sesame oil were found to be non-compliant. Unsaponifiable matter of oil samples ranged from 0.37 g/kg to 1.13 g/kg, which are within specified FSSR 2011 limits. Polenske values for coconut oil ranged from 15℃ to 16.02℃, meeting the required FSSR 2011 limit. Consequently, a higher Polenske value would suggest the existence of a high percentage of Free Fatty acids (FFA). As per the research by [22], These fatty acids have the property of being easily vaporized by steam, but cannot be dissolved in water. The DPPH free radical scavenging activity ranged from 25.2 % to 59.47% while the sesame oil showed high free radical scavenging activity. The research by [10][23] shows that antioxidants may either inhibit the formation of free alkyl radicals in the initial stage or interrupt the propagation of the free radical chain.

3.3 Analysis of adulteration in cold-press oils

The results of the adulterants in cold-pressed coconut, groundnut, and sesame oils are mentioned in Table 3. Coconut oil from the other four districts except Chennai showed the presence of mineral oil but the absence of argemone oil, when it comes to groundnut oil and sesame oil it was detected in both the presence of argemone oil and mineral oil. The Bellier test was conducted on groundnut and sesame oils, and their ranges were found to meet the requirements specified in FSSR 2011. To sum up, samples collected from the Chennai district are not shown for positive results for adulterants; while for other samples mineral oil and/or argemone oil were found positive.

3.4 Fatty acid profile by GC-FID

Table 4 depicts the fatty acid compositions of three different oils determined by Gas chromatography with flame ionization detector GC-FID. The coconut oil samples show predominant fatty acids, i.e., lauric acid, with a concentration of 45.63 g/100 g. The groundnut and sesame oil samples have the most palmitic acid, even though they also contain other saturated fatty acids at levels between 10.05 g/100g to 14.07 g/100g and 10.17g/100g to 10.99 g/100g, respectively. The higher levels of oleic acid (6.41, 39.9, and 43.04 g/100g) are found in the monounsaturated fatty acids of coconut, groundnut, and sesame oil from Chennai districts. From Chengalpattu, the groundnut and sesame oils have oleic acid levels of 41.95g/100g and 42.87 g/100g, respectively. The samples of coconut, groundnut, and sesame oil contain polyunsaturated fatty acids, with linoleic acid in amounts of 2.42 g/100g, 33.65 g/100g, and 38.03 g/100g, respectively. Whereas in groundnut and sesame oil, the linoleic acid content is 34.85 g/100g and 37.56 g/100g, respectively. Trans fatty acids in oil samples are within the FSSAI-specified limit. The findings suggest that the saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids found in the samples conform to the specifications outlined in the FSSR (2011) standard. The research by [24] shows the most eminent fatty acid (oleic acid) in cold-press groundnut and sesame oil are 45.07% and 39.20%, whereas in palmitic acid the presence was around 13.81% and 10.79%.

3.5 Vitamins D_3, and E in edible oil by HPLC

High-performance chromatography with an ultraviolet detector shows the presence of vitamin D_3 and E in coconut, groundnut, and sesame oil. However, animal fats, such as vitamin D_3 do not fortify the specified 15 samples. The presence of vitamin E was not detected in groundnut and sesame oil from Chengalpattu district. However, vitamin E naturally exists in coconut oil from the Chennai district, with a range of 0.1059mg/g to 0.1622mg/g. Factors such as packing and storage temperature affect the stability of vitamin E, causing its concentration to decline over time indicated by [25]. Fig. 1 shows the chromatogram of vitamin E presence in coconut oil.

3.6 Trace elements by ICP-MS

The results of elemental analysis (Pb, Cd, As, Hg) carried out by in ICP-MS exhibited that, there are no evidence for the presence of trace elements as they were in the range of below detection limits (≤0.05 mg/kg). Toxicity, freshness and storability of edible oils can be assessed by trace element analyzes. Metals such as Cd, Cr, Hg, Ag, and Pb are significant due to their toxicity and metabolic function studied by [26-27]. The occurrence of specific trace elements can induce oxidation reactions, leading to the production of peroxides, aldehydes, ketones, acids, epoxides, and other chemical compounds. As per FSSR (2011) standards, the maximum limit for Hg is 0.25 mg/kg, As is 0.1 mg/kg, Pb is 0.1 mg/kg, and Cd is 0.1 mg/kg.

4. Conclusions

A comprehensive survey was conducted to assess the safety and quality of cold-pressed coconut, groundnut, and sesame oils across various districts of Tamil Nadu, adhering to the standards outlined in FSSR 2011 and Indian standards 1964. Physical parameters such as refractive index, cloud point, color, pH, moisture content, and specific gravity were evaluated, demonstrating compliance with regulatory limits in most cases. Notably, coconut oil samples generally met specified standards, while some groundnut and sesame oil samples showed deviations, particularly in specific gravity. Chemical analysis revealed favourable acid, free fatty acid, iodine, saponification, and Polenske values across coconut oil types, with sesame oil exhibiting robust antioxidant activity. Groundnut oil displayed lower free radical-scavenging activity compared to coconut and sesame oils. Adulteration analysis indicated a minimal presence of mineral oil in coconut oil from Chennai districts, while most of the groundnut and sesame oils were susceptible to adulteration in the presence of argemone oil, although not in Chennai samples. Fatty acid profiles demonstrated predominant fatty acid compositions in each oil type, with variations observed across districts. Vitamin D_3 and E analysis highlighted the natural presence of vitamin E in coconut oil from Chennai, whereas groundnut and sesame oils from Chengalpattu lacked detectable vitamin E. Trace element analysis via ICP-MS indicated concentrations below permissible limits, reinforcing the safety of the oils for consumption. Overall, the survey revealed varying quality attributes across districts, with cold-pressed oils from the Chennai district exhibiting superior quality and safety compared to other regions.

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