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IMPACT OF HEATING ON OLIVE OIL: OXIDATIVE CHANGES AND PHYSICOCHEMICAL PROPERTIES

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Highlights

- Unraveling the Impact of Heating on Olive Oil.
- Experimenting with Olive Oils Chlorophyll and β-carotene Dynamics.
- Investigating the Transformation of Olive Oils Nutrients.

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ABSTRACT: This study aimed to analyze the physicochemical parameters of various brands of olive oil (OO) available in the local markets of Hyderabad, Pakistan. The parameters studied include concentrations of chlorophyll, β-carotene, free fatty acid (FFA), conjugated diene (CD), conjugated triene (CT), and oxidative stability. The results showed that none of the analyzed (OO) is recommended for cooking due to high FFA levels, but all except one could be used as salad oil. Through a systematic analysis, we also examined the impact of heating on chlorophyll and β-carotene levels in commercial OO brands. Our findings elucidate the varying responses of OO brands to heating, with distinct alterations observed in chlorophyll, and β-carotene levels. Furthermore, the FTIR analysis provided valuable insights into the molecular changes and oxidative stability of the oils under different heating conditions. These findings have significant implications for both consumers and the OO industry, as they provide valuable insights into the selection of high-quality OO brands that maintain their nutritional integrity and flavor profiles during cooking.

Keywords: *Extra Virgin Olive Oil, Bioactive Compounds, Heating Effects, Oxidative Stability, Quality Control*

1. INTRODUCTION

Refined Olive Oil (ROO) is obtained by refining methods from virgin olive oil (VOO) that do not modify the original composition of triacylglycerol in the oil [1]. Pure olive oil (OO) with a lighter color, more neutral taste, and oleic acid ranging from 55-83%, is a lower quality oil than extra virgin olive oil (EVOO) or VOO. Pure OO is known as an all-purpose cooking oil. Usually, this oil is a combination of VOO and refined OO [2]. A significant first step would be to improve the production of useful EVOO by classifying olives based on their FFA content prior to processing [3]. In this way, during the extraction process, mixing of high and poor quality oils could be avoided [4]. Heating OO can lead to the oxidation of the oil and the formation of harmful compounds [5]. The quality of OO deteriorates as it is exposed to high temperatures, such as during cooking or frying [6]. The oxidative stability of OO which indicates its resistance to oxidation and degradation, decreases with increasing temperature and exposure time [7]. Therefore, it is recommended to use OO for cooking at lower temperatures and for shorter periods. EVOO has a lower smoke point than other oils, making it less suitable for high-temperature cooking [8]. Overall, the heating effect of OO should be considered when using it for cooking or frying, and it is important to use proper cooking techniques to minimize the production of harmful compounds [9]. The aim of the present investigation was to evaluate the physicochemical characteristics of OO commercially available in the market according to the standard AOCS methods. In addition, oxidative stability of OO at various temperatures and FTIR characterization were also done. Prior research on OO quality has typically examined individual parameters in isolation, often with methodological limitations. Our study

provides a more comprehensive assessment by simultaneously evaluating oxidative stability, color, FFA, chlorophyll, and β-carotene - key quality markers that interact during heating. Unlike previous approaches, we establish meaningful correlations between these parameters while employing rigorous analytical protocols. This integrated analysis offers practical insights for quality control, addressing gaps in current understanding.

2. MATERIAL AND METHODS

2.1. Chemicals

The reagents and chemicals used in this research such as sodium hydroxide, n-hexane, potassium iodide, sodium thiosulfate, potassium hydroxide, methyl alcohol, carbon tetrachloride, potassium bromide, hydrochloric acid, sulfuric acid, ethyl alcohol, and sodium sulfate anhydrous were bought from E-Merck (Darmstadt, Germany).

2.2 Sample collection

Samples of OO were obtained from local markets and stored at 4°C for further chemical analysis. Samples were coded as O-1 Ripe and Sweet Extra Virgin Olive Oil (RS EVOO), O-2 Natural Olive Oil, O-3 Borges Olive Oil, O-4 Sasso Olive Oil, O-5 Al- Amir Olive Oil, O-6 Refined and Sweet-Ripe Premium Olive Oil (RS- RPOO), O-7 Mondial Olive Oil, O-8 Marhaba Olive Oil, O-9 Al- Rachid, O-10 Consul Olive Oil, O-11 Olio Olive Oil, and O-12 Signature Cold Press Olive Oil.

2.3. Physicochemical parameters of OO

The physicochemical properties of OO, including Free Fatty Acid (FFA) content, conjugated diene (CD) and conjugated triene (CT) levels, β-carotene concentration, chlorophyll content, color, and oxidative stability were assessed in this study. The analysis was carried out using standard methods and protocols.

2.3.1. Determination of free fatty acid

The official procedure of AOCS Ca 5a-40 was used to quantify the amount of FFA in OO samples. In the conical flask (250 mL) added hot neutralized alcohol of exactly 50 mL and an indicator of 2 mL. The conical flask content was titrated with sodium hydroxide solution (0.1 M) until the pink color appeared. Approximately 56 g of OO sample was added into alcohol (neutralized) and titrated again, the solution constantly shaken until a permanent pink color seemed to be of a similar quality prior to sample addition [10]. The following formula was used for the calculation of FFA in OO samples.

$$FFA\% = \frac{28.2 \times V(mLNaOH) \times N\ (NaOH)}{W}$$

Where,
N= Normality of NaOH solution
V= Volume, mL of NaOH used in titrating the sample
W= mass, grams of test portion

2.3.2. Determination of conjugated diene and triene

CD and CT values were calculated as explained in the IUPAC II.D.233 analytical method (IUPAC, 1979) [11]. Around 250 mg of OO was weighed and transferred into a 25 mL volumetric flask and added isooctane. The properly homogenized sample was placed into a quartz cuvette. In

a spectrophotometer, absorbance at 232 and 270 nm was measured using isooctane as the blank solvent.

2.3.3.β-Carotene

β-carotene of OO samples was determined according to Brahmi et al., [12]. Firstly, the OO sample (1 g) was taken in a Falcon tube and diluted up to 20 mL with petroleum ether. A Perkin Elmer Lambda 25 UV-visible spectrophotometer was used to measure the carotenoid fraction at wavelengths between 440 and 480 nm.

$$\beta - Carotene = A\,\lambda_{max}\frac{10^5}{2650}$$

2.3.4. Chlorophyll

Chlorophyll content in OO samples was determined as reported by Kiritsakis*et al.,* [13] using air as a reference and noted the absorbance at 630, 670, and 710 nm, respectively.

The overall chlorophyll content calculation was as follows:

$$Chlorophyll\ (mg/kg) = [\,A670 - \frac{(A630 - A710)}{2}\,]/\,(0.901 * L)$$

L is the cell thickness (cm), and A is the absorbance of the oil at the respective wavelengths.

2.3.5. Color

The official AOCS method Cc 13b-45 was used to verify the color of OO samples. In this procedure, the assessment of the oil color was done by comparing it with glasses of proven color properties. The refined and crude OO was kept in 1 and 5 inches (25.4 mm and 127 mm) cells, respectively, and placed in a Lovibond Tintometer. By obtaining the best possible match with the standard color slide, the OO sample color was decided [10].

2.3.6. Oxidative stability

The Rapidoxy instrument was used to measure the oxidative stability of OO. To know the stability of the oil, weighed around 5 g samples kept them in the test chamber, and applied 700 kPa (O_2) pressure at a fixed temperature (120 ^oC) to accelerate the oxidation process. The test was completed when the pressure fell below the 10% p_{max} value.

2.3.7. Effect of heating on the β- carotene and chlorophyll content

To check the effect of heating on the β-carotene and chlorophyll content, the OO samples were heated for 8 h according to traditional methods of frying. The oils were subjected to varying temperatures (110, 120, 130, and 140 ^oC) to expedite the oxidation process. This was achieved by heating the oils in a stainless steel shallow pan, measuring 20-30 cm in diameter, over a gas flame. No food was added during this experiment, as the focus was solely on examining the impact of heating on the oils. After the heating process, the β-carotene and chlorophyll content in the OO samples was measured to determine how the different temperatures affected these components.

2.3.8 FTIR characterization of Olive oil

Infrared (IR) spectra were collected using the FT-IR spectrometer(Thermo Nicolet iS10) with DTGS as the detector to track the consistency and oxidative degradation of OO. FTIR set to 4 cm^{-1} resolution, 4000-650 cm^{-1} range, scans 16, and SB-ATR diamond crystal accessory. Before the study of samples, a background spectrum was collected. For capturing the spectra, approximately 50 µL of the oil sample was placed on the diamond crystal. To collect the FTIR data and instrumental control OMINIC software (Version 9) was used.

2.3.9. Statistical analysis

The data was subjected to statistical analysis using Minitab16 USA software. The analysis involved performing a variance analysis (ANOVA) followed by the Tukey test with a significance level of $p \leq 0.05$. The reported results for each data point consist of the mean value along with its corresponding standard deviation (mean ± SD), and three replicates were considered in the analysis.

3. Results and Discussion

Typically, at first glance, buyers judge the consistency of foods from their appearance, such as (shape, texture, and color), so this appraisal affects the decision of whether or not to buy it. This is partially linked to food color, which usually shows the stage of ripeness, the conditions of industrial processing/ agricultural production, and other variables. In contrast, color is synonymous with food consistency, which plays a vital role in buying oil by customers.

3.1 Color

The OO color is much related to its apparent feature and consequently to its acceptability. In current research work, the yellow, blue, and red color in commercial OO samples was determined by Tintometer and found in the range from 40.65 to 3.05, 1.0 to 7.0, and 2.0 to 5.35, respectively. The summarized results of the yellow, blue, and red color index of commercial OO are shown in Table 1. Such color evaluations are essential as they influence the perceived quality and acceptability of the product among consumers.

Table 1. Color index of commercial OO

Samples	YELLOW (Y)	BLUE (B)	RED (R)
O-1	31.0±0.51e	1.5±0.01h	5.05±0.34b
O-2	26.0±0.61	6.5±0.31b	5.35±0.91a
O-3	42.0±0.41b	6.0±0.41c	4.0±0.06d
O-4	11.2±0.70i	1.95±0.21g	3.25±0.13f
O-5	22.0±0.43h	4.0±0.12e	3.65±0.06e
O-6	43.0±0.47a	7.0±0.59a	5.2±0.07ab
O-7	30.1±0.61f	1.0±0.40j	2.0±0.41h
O-8	31.1±0.67e	1.4±0.04h	5.2±0.84ab
O-9	32.1±0.56d	1.2±0.03i	4.1±0.41cd
O-10	40.7±0.06c	1.4±0.02h	4.35±0.91c
O-11	40.65±0.33c	5.5±0.21d	3.75±0.77e
O-12	3.05±0.34j	2.4±0.02f	2.65±0.06g
P-value	7963.87***	3605.25***	141.12***

3.2 Free fatty acid (FFA)

The acidity level significantly influences the quality of VOO. Furthermore, it is commonly employed as a conventional criterion for the classification of OO grades. The quality of the VOO is inversely proportional to the value of this factor. The rise in acidity can be primarily attributed to enzymatic activity resulting from the damage to olive tissue. FFA is the key parameter used to scrutinize the various types of OO. In our results, FFA was found to range from 1.22 to 1.65% (Table 2). The higher FFA content was noted in O-5. On the other hand, a lower value of FFA was determined in O-12.

3.3. Conjugated diene (CD) and triene (CT)

The lower quality of OO has a higher quantity of CD formed due to oxidative processes in the oil. A lower absorption value in the spectrum region from 200 to 300 nm indicates better quality of OO and a higher absorption value describes the lower quality of oils. In our results, CD was found to range from 0.40 to 1.31 (Table 2). The highest value suggests a greater oxidation rate. On the other hand, initially, the rate of CD formation was smaller but increased with storage time or heating. In our results, CT was found in the range of 0.42 to 3.05 (Table 2).

3.3. β-carotene

Pigments are responsible for the color of OO and are an important constituent that is directly related to the quality of oil. OO contains a relatively rich variety of carotenoids (i.e., β-carotene). Our research findings revealed that the β-carotene content in the analyzed OO samples varied between 1.70 to 8.46 mg/kg. Particularly, O-12 exhibited a notably higher amount of β-carotene compared to other samples, while O-3 showed a relatively lower value of β-carotene content (Table 2). These results highlight the significance of β-carotene in determining the color and quality differences among various types of OO.

3.4. Chlorophyll

The color of OO is mainly due to the presence of pheophytins a & b in fresh oils. The level of chlorophyll (and carotenoids) depends on many factors such as genetics, degree of fruit ripening, and extraction technology. The chlorophyll content decreases as the fruit ripens. In this study, chlorophyll content was found in the range of 3.2 to 166.7 mg/kg (Table 2).

3.5. Oxidative stability

The oxidative stability of VOO is heavily influenced by the cultivar and is impacted by various factors, including the composition of fatty acids, phenolic compounds, and tocopherols. The sample with the highest oxidative stability (29.3 h) was found to be O-1, while the sample with the lowest oxidative stability (11.8 h) was O-11. In contrast, O-12 exhibits an intermediate level of oxidative stability, as indicated by a value of 19.2 h (Table 2). The enhanced resistance to oxidation observed in O-1 can be attributed to its elevated concentration of phenolic compounds, reduced linolenic acid content, and elevated levels of monounsaturated fatty acids. Contrarily, O-11 exhibits lower stability compared to O-1 and O-12 due to its high linolenic acid content, which makes it highly susceptible to oxidation, and its relatively lower amount of monounsaturated fatty acids.

Table 2. Physicochemical parameters of commercial Olive oil samples.

Sample	FFA (%)	CD	CT	β-carotene (mg/kg)	Chlorophyll (mg/kg)	Oxidative stability (h)
O-1	1.60±0.42d	0.40±0.11j	1.69±0.45g	7.19±0.15c	107.2±0.36ab	29.3±0.21a
O-2	1.26±0.34h	0.56±0.37i	3.05±0.34a	5.45±0.78f	24.4±0.33c	15.2±0.13e
O-3	1.37±0.47f	0.73±0.20f	1.90±0.28f	1.70±0.59l	3.20±0.12c	13.0±0.48h
O-4	1.33±0.38g	0.72±0.13f	1.18±0.31h	7.02±0.97d	28.7±0.82bc	12.9±0.27h
O-5	1.65±0.35b	0.90±0.52d	2.47±0.75b	5.21±0.12g	38.0±0.58bc	14.2±0.13f
O-6	1.34±0.37g	0.86±0.11d	2.39±0.86c	2.49±0.72k	59.5±0.78bc	14.0±0.41g
O-7	1.40±0.43e	0.83±0.11e	2.24±0.22d	6.39±0.87e	37.1±0.28bc	23.7±0.84b
O-8	1.62±0.40c	0.69±0.07g	2.50±0.71b	7.90±0.56b	56.0±0.58bc	18.0±0.48d
O-9	1.38±0.32ef	0.73±0.09f	2.17±0.35e	4.21±0.12i	63.6±0.01abc	12.0±0.41j
O-10	1.39±0.30ef	0.64±0.01h	1.69±0.44g	3.47±0.75j	58.8±0.70bc	12.2±0.14i
O-11	3.31±0.98a	1.16±0.27b	2.47±0.76b	4.25±0.06h	17.30±0.12c	11.8±0.70k
O-12	1.22±0.40i	1.31±0.47a	0.42±0.22i	8.46±0.76a	166.7±0.98a	19.2±0.70c
P-value	6683.83***	1959.49***	1592.58***	131715.06***	1.85**	10193.44***

Table 3. Pearson correlation of physicochemical properties of Olive oil.

Parameters	FFA	CD	CT	β-carotene	Chlorophyll	OSI
FFA	1					
CD	0.199	1				
CT	0.344	0.392	1			
β- carotene	-0.119	-0.492	-0.522	1		
Chlorophyll	-0.29	-0.565	-0.675	0.573	1	
OSI	-0.196	-0.519	-0.407	0.673	0.479	1

Table 3 shows the correlation of studied parameters such as FFA, CD, CT, β-carotene, chlorophyll and oxidative stability of commercial OO samples. It was observed that FFA showed a negative correlation with β-carotene, chlorophyll, and OSI, while a positive relationship with CD and CT. A strong negative correlation was noted between CD toβ-carotene, chlorophyll, and OSI, while a positive correlation of CD was observed with CT and FFA. On the other hand, β-carotene showed a strong positive correlation with chlorophyll and OSI. A strong negative correlation was noted with CD and CT, while a least positive correlation was observed with FFA. A strong positive correlation was observed between chlorophyll to β-carotene and OSI, whereas a negative relationship was noted between FFA, CD, and CT. In contrast, OSI showed a strong positive relationship with β-carotene and chlorophyll, while a strong negative correlation was noted with CD and CT and the least with FFA.

3.6. β-carotene and chlorophyll content in olive oil after heating

Recent studies have shown that heating olive oil can alter its levels of chlorophyll and beta-carotene. The degradation and alterations of chlorophyll and β-carotene, which are sensitive to temperature and oxidation, can occur when they are subjected to heat. These changes have the potential to impact their concentrations and the potential health benefits they offer.

Scholarly investigations have been conducted to examine the influence of heating on the phytochemical composition of olive oil. An investigation conducted by [14] explored the degradation process of chlorophyll and carotenoids in VOO under the influence of eating. The findings of the study demonstrated a decline in the concentrations of these compounds as the temperature of heating escalated. A similar trend was also observed in the present study when OO was subjected to heat at different temperatures. The β-carotene and chlorophyll content of OO before and after heating are shown in Tables 4A and 4B

Table 4a β-carotene content in OO before and after heating

Sample	β-carotene (mg/kg)	Temperature (°C)			
		110	120	130	140
O-1	7.19±0.30d	6.89±0.34a	4.73±0.26b	4.11±0.58a	2.48±0.05bc
O-2	5.95±0.23j	4.94±0.21g	3.93±0.17d	2.03±0.38h	0.33±0.07h
O-3	6.23±0.28f	5.78± 0.23d	4.74±0.78b	3.20±0.13c	2.43±0.09c
O-4	7.22±0.34c	6.50±0.32c	4.96±0.47a	3.22±0.81c	2.00±0.42e
O-5	5.21±0.20k	3.79±0.34k	2.94±0.50g	1.56±0.05i	0.24±0.08i
O-6	2.99±0.14l	1.78±0.08l	2.58±0.31h	2.30±0.60e	2.28±0.03d
O-7	6.79±0.33e	5.17±0.25f	3.06±0.34f	2.03±0.38h	2.00±0.25e
O-8	7.90±0.39b	5.26±0.27e	3.94±0.50d	2.16±0.47g	2.50±0.35b
O-9	6.12±0.30g	4.21±0.21j	4.09±0.29c	3.89±0.58b	2.82±0.67a
O-10	5.99±0.29i	4.61±0.23i	3.75±0.77e	2.69±0.86d	1.89±0.58f
O-11	6.06±0.24h	4.84±0.22h	3.94±0.50d	2.24±0.07f	1.59±0.30g
O-12	8.96±0.44a	6.61±0.27b	4.74±0.79b	2.06±0.34h	0.04±0.13j
P-value	68962.71***	59934.25***	19134.13***	2103.76***	3000.45***

Table 4b Chlorophyll content in OO before and after heating

Samples	Chlorophyll (mg/kg)	Temperature (°C)			
		110	120	130	140
O-1	105.05±0.48b	94.90±0.06b	88.0±0.48b	79.90±0.63a	25.90±0.63b
O-2	24.20±0.13l	22.30±0.63i	19.90±0.63j	12.90±0.56l	3.10±0.07h
O-3	26.30±0.05k	24.10±0.34h	18.30±0.06l	14.50±0.41j	4.0±0.62f
O-4	28.40±0.34i	23.0±0.12i	19.20±0.20k	19.0±0.43g	16.90±0.63d
O-5	37.80±0.41g	31.20±0.28e	25.10±0.34h	19.30±0.06f	4.90±0.12e
O-6	59.10±0.27d	47.30±0.70d	36.90±0.56d	17.90±0.56h	3.10±0.41h
O-7	36.90±0.06h	26.60±0.41f	20.10±0.34d	14.0±0.48k	3.30±0.22g
O-8	53.80±0.41f	25.10±0.48g	35.10±0.27e	21.30±0.99e	3.10±0.22h
O-9	64.80±0.70c	48.0±0.13d	30.0±0.48f	16.90±0.63i	3.0±0.42i
O-10	58.80±0.63e	49.80±0.03c	42.20±0.20c	34.20±0.13c	27.0±0.56a
O-11	27.60±0.77j	26.90±0.56	26.10±0.27g	25.10±0.34d	25.0±0.84c
O-12	164.50±0.13a	136.0±0.41a	96.10±0.34a	54.10±0.34b	2.20±0.14j
P-value	24155541.96***	18704.04***	1648484.90***	641379.09***	225284.42***

3.7. FT-IR Characterization

IR spectroscopy is useful for determining molecular structures because of the abundance of data it provides and the ability to attribute certain absorption bands to functional groups. The majority of the peaks and shoulders observed in the spectrum of fats and oils can be attributed to the distinctive functional groups present. This is evident in the typical spectra of O-12, as depicted in Figure 1A. The observable peaks attributed to the stretching mode of C–H bonds occur within the wavenumber range of 2800–3100 cm^{-1}. Similarly, the stretching of C=O bonds can be observed within the range of 1700–1800 cm^{-1}. Additionally, the stretching of C–O–C bonds and the bending of C–H bonds can be easily observed within the range of 900–1400 cm^{-1}. The spectra of oils exhibited a nearly indistinguishable range, with only subtle differences discernible upon close examination. The observed phenomenon can be attributed to the comparable chemical composition of the oils under consideration. It has been reported that IR analysis relies heavily on data from the wave number ranges 3100-2800 cm^{-1} and 1800-900 cm^{-1} [15]. Figure 1B illustrates the group spectra of OO in the wavenumber range of 4000-650c m^{-1}.To check the possible effect on the intensity of various functional groups during heating, one representative sample

was selected. Table 5 shows FT–IR spectral changes in the functional groups present in OO before and after heating. It was observed that negligible change appeared in the intensities of various functional groups during heating.

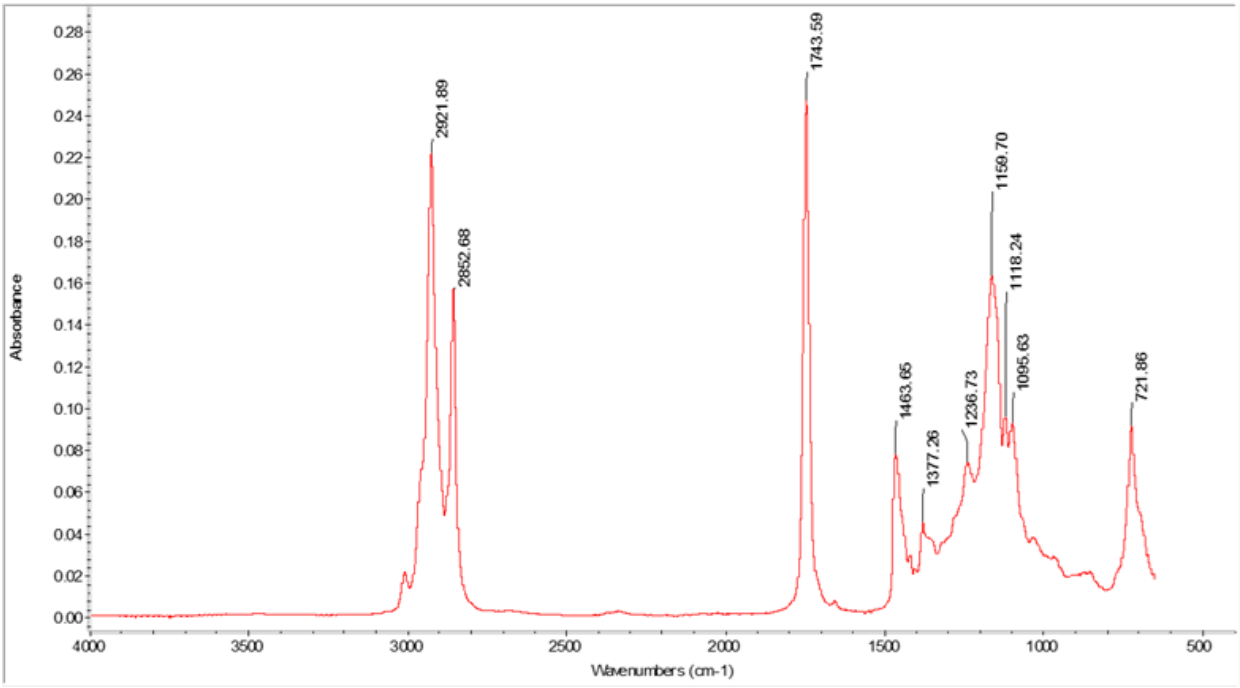

Figure 1A. Representative FT- IR spectrum of O-12

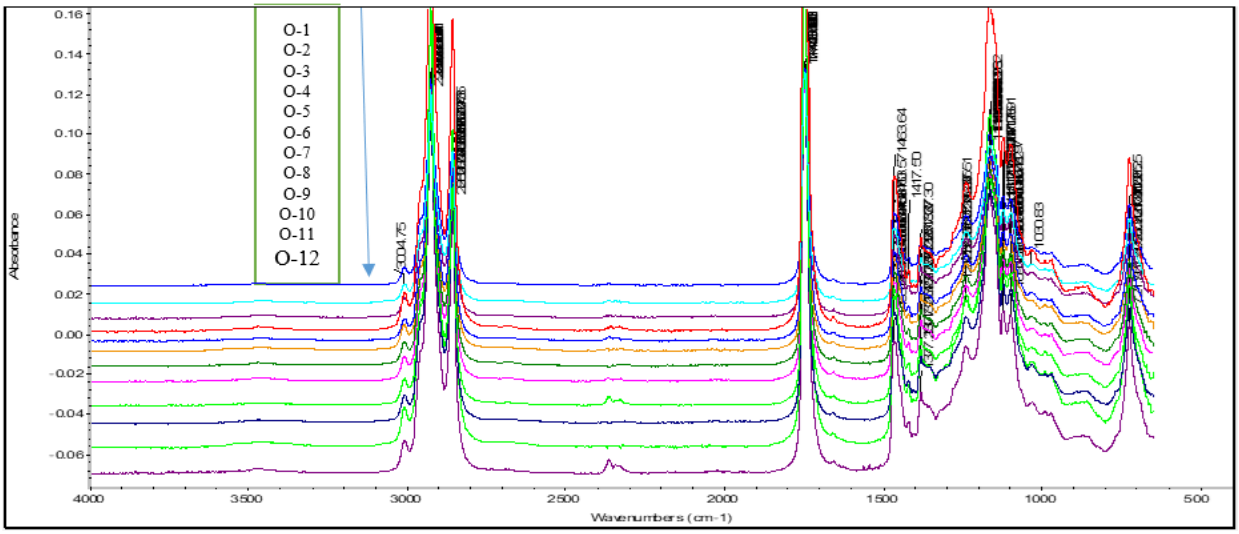

Figure 1B. FT- IR group spectra of commercial Olive oil

Table 5. Shows FT–IR spectral changes in the functional groups present in OO Samples

Sample	Functional group	=C–H (cis)	–C–H (CH3)	–C–H (CH2)	–C–H (CH2)	–C=O (ester)	–C–H (CH2)	–C–H (CH3)	–C–O –CH2–	–C–O –CH2–	–C–O	**C-C-O**	**CH**	CH
	Nominal Frequency cm^{-1}	**3004**	**2929**	**2921**	**2852**	**1743**	**1463**	**1377**	**1236**	**1160**	**1117**	**1095**	**965**	**721**
Intensity	Before Heating	0.03	0.04	0.21	0.15	0.23	0.07	0.04	0.07	0.l6	0.09	0.09	0.08	0.03
O-1	After Heating	0.02	0.03	0.22	0.15	0.23	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.04	0.21	0.15	0.23	0.07	0.04	0.07	0.l5	0.09	0.09	0.08	0.03
O-2	After Heating	0.02	0.03	0.21	0.15	0.23	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.04	0.21	0.15	0.23	0.07	0.04	0.07	0.l5	0.09			
O-3	After Heating	0.02	0.03	0.21	0.15	0.23	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.04	0.21	0.15	0.23	0.07	0.04	0.07	0.l6	0.09			
O-4	After Heating	0.02	0.22	0.21	0.15	0.23	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.02	0.21	0.15	0.23	0.07	0.04	0.07	0.158	0.09			
O-5	After Heating	0.02	0.22	0.21	0.15	0.23	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.02	0.21	0.15	0.24	0.07	0.04	0.07	0.161	0.09			
O-6	After Heating	0.02	0.22	0.22	0.15	0.23	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.02	0.21	0.15	0.24	0.07	0.04	0.07	0.161	0.09			
O-7	After Heating	0.02	0.22	0.22	0.15	0.23	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.02	0.22	0.15	0.24	0.07	0.04	0.07	0.16	0.09			
O-8	After Heating	0.02	0.22	0.22	0.15	0.23	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.02	0.22	0.15	0.25	0.07	0.04	0.07	0.16	0.09			
O-9	After Heating	0.02	0.22	0.22	0.15	0.24	0.07	0.04	0.07	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.02	0.21	0.15	0.23	0.07	0.04	0.07	0.15	0.08			
O-10	After Heating	0.02	0.22	0.22	0.15	0.23	0.07	0.04	0.04	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.02	0.21	0.15	0.24	0.07	0.04	0.07	0.16	0.09			
O-11	After Heating	0.02	0.22	0.22	0.15	0.24	0.07	0.04	0.04	0.16	0.09	0.09	0.08	0.03
Intensity	Before Heating	0.03	0.04	0.018	0.16	0.24	0.08	0.05	0.06	0.16	0.1			
O-12	After Heating	0.02	0.03	0.22	0.16	0.24	0.08	0.05	0.16	0.16	0.09	0.09	0.08	0.03

4. CONCLUSIONS

In conclusion, our research conducted a comprehensive analysis of important factors such as chlorophyll, β-carotene, FFA, CD, CT, and oxidative stability in various commercially available OO products. The findings suggest that the utilization of analyzed oils for culinary purposes should be discouraged due to the presence of elevated levels of FFA. Furthermore, our study on the impact of heating on chlorophyll and β-carotene revealed distinct responses based on the brand of the samples. These findings were further supported by the analysis of molecular changes and oxidative stability using FTIR. The aforementioned findings are of great importance, as they provide valuable guidance to consumers and the olive oil industry in choosing high-quality olive oil brands that maintain their nutritional value and flavour profiles, even when subjected to the demands of cooking.

Declaration of Ethical Standards

I hereby declare that this paper adheres to the highest ethical standards. It is based on honest research and original work. All sources are properly cited, and no data has been falsified. I have avoided any form of plagiarism and have given appropriate credit to all contributors

Credit Authorship Contribution Statement

All authors made substantial contributions to this paper. Each person was involved in the research, writing, and final approval of the manuscript. We all take responsibility for the work and its accuracy.

Declaration of Competing Interest

I have no competing interests to disclose. This research was conducted without any financial or personal conflicts that could influence the results.

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Data Availability

Feel free to modify the contact information as needed!

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