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Blending Camelina Oil with Olive Oil to Improve Stability and Nutritional Properties

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ABSTRACT

This study evaluated the nutritional and oxidative properties of blended Camelina oil (CO) and virgin olive oil (VOO) at different ratios (75:25, 50:50, and 25:75 (w/w)). The physicochemical characteristics of the blends, including fatty acid profiles, antioxidant activity, smoke point, total phenolic compounds, tocopherol content, unsaponifiable matter, and oxidative stability, were analyzed. The results revealed that increasing the proportion of VOO led to a decrease in polyunsaturated fatty acids (PUFA) (48.36%, 40.55%, 31.55%, 21.89% and 13.97%) and an increase in monounsaturated fatty acids (MUFA) (37.47%, 44.42%, 52.10%,60.31%, and 66.58%), improving thermal stability (2.77h, 3.9h, 4,92h, 6.7h, and 8.94h). A 75%:25% ratio of CO to VOO provided the best balance of fatty acid composition and optimal omega-6 to omega-3 ratio (0.93) along with more nutritional benefits such as high levels of bioactive compounds (tocopherols 689.11mg/kg). The study highlights the potential of blending oils to create healthier, more stable products with enhanced nutritional properties, leading to the development of new edible oil blends with improved nutritional quality and stability.

Keywords: Camelina oil, Virgin olive oil, Blending, Oxidative stability, Fatty acid composition

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INTRODUCTION

Nowadays, high-fat intake and improper diet are considered food-related risk factors including heart diseases, cholestasis, hypertension, and obesity. However, to provide desirable physical, nutritional, and sensory quality of the food, a balanced diet that encompasses more than 40% fat, is requisite. Moreover, the factors involved in the evaluation of the nutritional value of edible oils include fatty acid (FA) composition, positioning of FAs in triglyceride structure, and unsaturation degree. Edible vegetable oil as a vital part of the daily diet is considered an integral ingredient in cooking recipes. In most cases, however, the application of original forms of edible oils is restricted due to some specific physicochemical characteristics and short shelf life as well as the low nutritional value of food products which reduce consumer satisfaction [1]. Also, the balanced ratio of ω6/ ω3 FAs is another issue of vegetable oils since the best ratio of ω-6 / ω-3 brings health to the heart [2].

Therefore, in the food industry, the attainment of economical and practical methods for increasing the shelf life, oxidative and thermal stability of vegetable oils, and optimization of ω6/ω3 FAs, is indispensable [2]. For this purpose, four different approaches; interesterification, fractionation, hydrogenation, and blending [3], have been applied for vegetable oil modification [4]. Among these techniques, blending two or more oils for the formulation of new desirable products has many advantages, such as FA profile regulation and the bioactive compound quantities and natural antioxidants in the recent admixtures [5]. Overall, these privileges increase nutritional characteristics, enhance oxidative durability, and produce a blend shelf life [1]. Also, research has proven the blending method results in minimal by-products and hazardous compounds compared to other mentioned techniques, such as hydrogenation. Therefore, in the current study, blending is applied to improve the properties of camelina oil [6].

Camelina sativa Boiss. (Camelina), belongs to the *Cruciferae* (Brassicaceae) family and is the oldest annual oilseed crop native, is native to Central Asia and the Mediterranean Region [7]. Different Camelina genes exhibited good tolerance to drought stress and biological stresses [8, 9]. Camelina has gained significant attention in recent years due to its ability to resist pests, insects, and weeds, its compatibility with various environmental qualifications, its low necessity for water, nutrients, and fertilizer, its excellent potential as an oilseed crop, its especially high amount of essential FAs (linoleic and a-linolenic, 35–40%), and protein (35–40%) [10]. The oil content of Camelina seed decreases under soil salinity; however, this detrimental effect can be alleviated through the foliar application of silicon [11]. Considerable studies have focused on optimal irrigation strategies for Camelina seeds [12]. Camelina Oil is a rich source of natural antioxidants (approximately 800 mg total tocopherol /kg), squalene, and flavonoids [13]. Furthermore, its role in avoiding atherosclerosis and tumors, inhibiting coronary heart disease, and regulating the immune system has been proven. Therefore, this oilseed crop has become an eminently suitable option in the food industry [13]. Despite its past, this oil has been considered as a new oil in Iran in

the last two years and its cultivation has been developed, so its targeted use is important to improve the nutritional health of foods. Therefore, due to the high level of linolenic fatty acid, which reduces stability, blending is one of the effective approaches for optimal utilization of this oil [10, 14]. This research group successfully cultivated Camelina seeds for the first time in Iran through continuous studies. In subsequent stages, its toxicity and safety were evaluated to assess its potential as an edible oil for human consumption. After conducting clinical trials and confirming its safety [14, 15], further research was conducted on a blend of Camelina oil and virgin olive oil, revealing its novel potential as a functional oil with enhanced health benefits.

Among vegetable edible oils, olive oil has become popular throughout the world because of its notable characteristics such as distinct taste and flavor and higher nutritional value. Olive oil is well-known for its significant concentration of monounsaturated fatty acids, particularly oleic acid (71 g/100 g) that have favorable effects on human health besides adequate resistance and stability. Because of its organoleptic specifications, and chemical and sensory profile oxidative stability, virgin olive oil has been the most popular olive oil. Owing to its acceptable shelf life, VOO can be mixed with other vegetable oils such as Camelina to raise its □ levels and durability. Due to its abundance of natural antioxidants and reduced unsaturation levels, VOO is recognized for its oxidation resistance. The order of abundance of FAs in VOO can be expressed as follows: monounsaturated fatty acids (ω9: oleic acid), saturated and PUFAs, and linoleic acid (ω6). The admixture of VOO with other, less stable edible oils has the potential to enhance its physicochemical properties and oxidative stability. This approach may also facilitate the attainment of optimal levels of linolenic acid (ω3) and oleic acid [16].

However, the proposed illustrations for mixing CO with other edible oils are not only nutritional but also economical. It is necessary to mention that no pure oil alone can meet all the demands of essential Fatty acids and vitamins. CO utilization combined with VOO could improve its oxidative stability. While CO is widely consumed oil globally, its stability during storage is reduced due to oxidation. Thus, it is a challenge to prevent CO oxidation.

MATERIALS AND METHODS

Materials

VOO was supplied directly from a research institute; Camelina oil extracted from the Soheil cultivar was obtained from Biston Shafa Company. All oil samples were stored at 5°C in aluminum foil-wrapped glass containers to avoid exposure to air, chemicals, and light. 2,2-Diphenyl-1-picrylhydrazyl (DPPH, approximately 90%) was obtained from Sigma (St. Louis, MO, USA). Various suppliers were the source of all chemicals and solvents used in high-performance liquid chromatography (HPLC) -grade analysis. Tocopherol standards (α, β, γ, and δ-tocopherol) were obtained from Calbiochem (La Jolla, CA).

Methods

Preparation for Oil Blends

To create three oil blends, a combination of CO and VOO was used in the following ratios: 25:75, 50:50, and 75:25 (w/w). The oils were mixed completely until they formed consistent blends at room temperature. For each run, a total of 100 grams of the combined oils was employed. The blends underwent mechanical stirring to ensure a uniform consistency. The resulting oil samples were, then transferred to glass bottles and stored at room temperature for future use.

Oil Characteristics Determination (physicochemical analysis)

Fatty Acid Composition

FA compositions of CO, VOO, and oil blend (25:75, 50:50, and 75:25, (w/w) CO/VOO) were determined by Gas Chromatography based on IUPAC [17]. Initially, FAMEs (FA methyl esters) were produced using methanolic potassium hydroxide through the following procedure: 100 mg of every oil sample was dissolved in 3 mL of hexane and then saponified with 100µL of KOH 2N. Subsequently, the sample was homogenized by a vortex mixer and reserved for precipitation. Then, FAs were identified using a 1 mL supernatant.

Gas-liquid chromatography was used to analyze FA methyl esters. The equipment used was a Hewlett Packard Model 6890 chromatograph with a Flame Ionization Detector (FID) and split/splitless injector. The injector temperature and detector temperature were both set at 210 °C, and the injection volume was 0.4 µL. The oven temperature was initially set at 110 °C for 10 minutes, followed by an increase to 200 °C at a rate of 10°C/min for another 10 minutes. Finally, it reached 200 °C and held isotherm for 40 min. The identification of FAs was conducted through a comparison of retention times with established standard values. To express the FA content, a percentage of the total weight was calculated [18, 19]. The flow rates of hydrogen were 30 and 300 mL/min, while nitrogen was used as a carrier with a flow rate of 15 mL/min. To determine the percentage of FA in the oil sample, the total area of all FAs in the sample was measured to the area of each individual sample.

Nutritional Properties

The oils' nutritional characteristics were assessed through various measures, such as the atherogenic index (AI), thrombogenic index (TI), hypocholesterolemic to hypercholesterolemic ratio (HH), PUFA to saturated fatty acid ratio (SFA), and omega-6 to omega-3 ratio. Equations 1 to 3 were used to determine these measures based on the levels of specific fatty acids [5].

$$AI = \frac{C_{12:0}+(4\times C_{14:0})+C_{16:0}}{\sum MUFA\omega 9+\sum\omega 6+\sum\omega 3} \quad \text{(Eq. 1)}$$

$$TI = \frac{C_{14:0}+4\times C_{16:0}+C_{18:0}}{0.5\times\sum MUFA+0.5\times\sum\omega 6+3\times\sum\omega 3} \quad \text{(Eq. 2)}$$

$$\mathrm{HH} = \frac{C_{18:1\omega 9}+C_{18:2\omega 6}+C_{20:4\omega 6}+C_{18:3\omega 3}+C_{20:5\omega 3}+C_{22:5\omega 3}+C_{22:6\omega 3}}{C_{14:0}+C_{16:0}} \quad \text{(Eq.3)}$$

Tocopherol

Based on the AOCS (American Oil Chemists' Society) procedure (1997), quantitative analysis of the different tocopherol forms (alpha, beta, and gamma) was performed in Acme 9000 (Young Lin, Korea) HPLC equipment consisting of a UV-VIS detector system and 20 µL injection loop. In addition, separation was done by a normal-phase column (250mm * 3mm i.d) operating at room temperature. The mobile phase consisted of isopropanol/hexane (99.5/0.5, v/v), pumped with a flow rate of 0.5 mL/min. The standard of α, β, and γ-tocopherol isomers was dissolved in hexane (2:25, w/v) and employed for identification and quantification of the collected peaks. The tocopherol content in the oils was quantified as tocopherol mg/oil kg exploiting. Furthermore, external calibration curves were attained for each tocopherol standard [20].

Antioxidant Activity

Several procedures have been approved to consider the antioxidant potential of the oil as follows:

DPPH

In the present study, DPPH was used as a stable and commercial reagent to determine phenolic compounds and antioxidant potential. The addition of an antioxidant such as polyphenols leads to a decrease in absorption, proportional to the concentration and antioxidant activity of the compound, and the color changes from purple to pale yellow [21]. In the conventional DPPH method, methanol is used as a solvent, which does not dissolve oil. In preliminary studies, isooctane was used as a suitable organic solvent for dissolving both DPPH and oil samples [22, 23]. The oil mixture samples were combined with 4 mL of 0.10 mM DPPH in isooctane, shaken thoroughly, and left in darkness for 30 minutes. The UV-visible spectrophotometry was used to measure the absorbance of each solution at a wavelength of 517 nm compared to the corresponding control. The percentage of the DPPH radical scavenging was quantified through equation 4:

$$\text{AntioxidantActivity} = \frac{(\text{Absorbanceofcontrol} - \text{Absorbanceofthesample})}{\text{Absorbanceofcontrol}} \times 100 \quad \text{(Eq.4)}$$

Total Phenolic Content (TPC)

The number of phenolic compounds in the oil was measured using a spectrophotometer and the Folin-Ciocalteu reagent at a wavelength of 735 nm, following the method described by Capannesi *et al.* [24]. The concentration of phenolic compounds was determined by creating a calibration curve using gallic acid in methanol, with concentrations ranging from 0.04-0.40 mg/mL; the outcomes were shown as gallic acid equivalent. Analyses were executed three times for individual oils and blends [24, 25].

Oxidative Stability (Rancimat)

The Rancimat test, considered to be a swift, inexpensive, ordinary, and reproducible technique, provides information on the resistance of oils against oxidation. Therefore, the Rancimat apparatus was used to observe the oil samples' resistance to oxidation (Metrohm model 679). The induction period of the oil sample was measured by analyzing the conductometric properties of volatile acids while exposing 2.5 g of the oil to a temperature of 110±0.1ºC and a purified airflow rate of 2.5 mL/min [26]. The obtained data was presented as induction time in an hour, Describing the duration needed for the breakdown of hydroperoxides generated in the oil based on the specific oxygen and heating circumstances.

Smoke Point

The smoke point is the temperature at which oil starts to produce smoke and become visible fumes as a result of the chemical breakdown of its constituents. This parameter is determined using the AOCS procedure. The thermometer bulb was inserted in a conical flask sealed with a rubber bung containing two holes (one for letting in the air into the conical flask and the other for the thermometer) [27, 28]. The conical flask was heated till the oil sample began to smoke and at that point, the temperature was recorded.

Unsaponifiable Matter

Unsaponifiable matter refers to the compounds present in oils or fats that cannot be saponified by alkali hydroxides and can be extracted using ether. These compounds include hydrocarbons, sterols, and pigments. The unsaponifiable matter was deliberated based on the AOAC procedure No. 933.08 briefly, the oil saponification process was primarily performed with potassium hydroxide 0.5 N in alcohol, and the unsaponifiable matter was attained by liquid-liquid extraction applying diethyl ether. This isolated substance was evaporated and the solid residue was weighed [29].

Statistical analysis

The outcomes were presented as the average value plus or minus the standard deviation of three replicate experiments. The statistical software SPSS 16.0 (Chicago, IL, USA) was utilized to conduct ANOVA for the analysis, in a factorial experiment with a completely randomized design. The significance of differences ($p<0.05$), was determined using Duncan's multiple range post hoc test. All statistical analyses were performed using SPSS software.

RESULTS and DISCUSSION

In the present study, VOO and CO were mixed at various proportions and the effects of oil levels on some qualitative parameters of the final samples were monitored.

Fatty Acid Profile

The FA composition of vegetable oils plays a critical role in determining their physical, chemical, and nutritional characteristics. The characterization of oils is heavily dependent on their FA profile. Previous findings were consistent with the FA composition of VOO and Camelina oil analyzed in this study [5]. Results of the FA analysis on CO, VOO, and their blends are reported in Table 1. The data revealed that CO is a rich source of omega-3 FAs, with a high percentage of linolenic acid (26.91% w/w), whereas VOO contained much lower levels of omega-3 FAs (0.51% w/w). The FA profiles of the blended oils were significantly different ($p< 0.05$); increasing CO proportion in the blends significantly increased omega-3 FA content. As shown in Table 1, the main FAs in VOO were oleic, palmitic, and linoleic acids (64.85%, 15.92%, and 13.44%, respectively). CO ($P<0.05$) contained the highest level of α-linolenic acid (26.91%), followed by linoleic acid (19.72%). Studies indicated the presence of various FAs in CO, including oleic acid, linoleic acid, alpha-linolenic acid, eicosanoic acid, erucic acid, palmitic acid, stearic acid, and other minor FAs. The proportion of these FAs may vary depending on the origin and production of CO. According to the data shown in Table 1, incorporating varying amounts of CO into VOO led to a noteworthy rise in levels of monounsaturated and saturated FAs, while there was a significant reduction in levels of polyunsaturated FAs ($P<0.05$).

The oxidative stability of oils is greatly influenced by their FA composition, with linolenic acid (18:3) being highly vulnerable to oxidation due to its three double bonds, followed by linoleic acid (18:2). In contrast, oleic acid (18:1) is less reactive as it only has one double bond. The proportion of PUFAs to SFAs also plays a crucial role, as well as the calculated oxidation value, which are commonly used as indicators of an oil's tendency to undergo oxidation [10, 29]. Blending CO with VOO increased the oleic acid content, which could positively affect oxidative stability. The current research demonstrated that oxidative stability increased in all mixed oils with an increase in the amount of VOO.

Table 1 FA (%) composition of CO, VOO, and their blends

FA	CO	VOO	CO: VOO		
			(25:75%)	(50:50%)	(75:25%)
(C12:0)	0.06 ± 0.01 a	ND b	0.05 ± 0.01 a	0.08 ± 0.01 a	0.06 ± 0.01 a
(C14:0)	0.17 ± 0.03 a	0.05 ± 0.01 c	0.09 ± 0.01 bc	0.13 ± 0.01 ab	0.12 ± 0.01 b
(C16:0)	6.30 ± 0.35 e	15.92 ± 0.16 a	13.14 ± 0.48 b	10.87 ± 0.08 c	8.49 ± 0.04 d
(C16:1)	0.18 ± 0.01 e	1.42 ± 0.07 a	1.06 ± 0.07 b	0.82 ± 0.01 c	0.49 ± 0.01 d
(C17:0)	0.04 ± 0.01 c	0.07 ± 0.01 a	0.06 ± 0.01 ab	0.06 ± 0.01 ab	0.05 ± 0.01 b
(C18:0)	2.55 ± 0.09 b	2.60 ± 0.07 ab	2.63 ± 0.02 a	2.50 ± 0.02 bc	2.42 ± 0.01 c
(C18:1 t)	0.03 ± 0.01 b	0.04±0.01 a	0.03 ± 0.01 b	0.04 ± 0.01 a	0.04 ± 0.01 a
(C18:1 c)	17.59 ± 0.30 e	64.85 ± 0.22 a	54.00 ± 0.23 b	41.57 ± 0.04 c	29.39 ± 0.26 d
(C18:2)	19.72 ± 0.01 a	13.44 ± 0.03 e	14.82 ± 0.08 d	16.75 ± 0.01 c	18.31 ± 0.04 b
(C18:3t)	0.03 ± 0.03 bc	0.02 ± 0.02 c	0.02 ± 0.02 c	0.06 ± 0.01 b	0.09 ± 0.01 a
(C18:3)	26.91 ± 0.01 a	0.51 ± 0.01 e	6.62 ± 0.01 d	13.91 ± 0.01 c	20.89 ± 0.01 b
(C20:0)	2.03 ± 0.01 a	0.46 ± 0.01 e	0.85 ± 0.04 d	1.15 ± 0.01 c	1.50 ± 0.01 b
(C20:1)	15.42` ± 0.27 a	0.27 ± 0.01 e	4.10 ± 0.20 d	7.61 ± 0.08 c	11.34 ± 0.12b
(C20:2)	1.70 ± 0.03 a	ND e	0.43 ± 0.01 d	0.83 ± 0.01 c	1.26 ± 0.01 b
(C22:0)	0.46 ± 0.02 a	0.13 ± 0.01 d	0.23 ± 0.02 c	0.28 ± 0.01 bc	0.37 ± 0.01 b
(C22:1)	3.56 ± 0.12 a	ND e	0.93 ± 0.07 d	1.74 ± 0.01 c	2.64 ± 0.05 b
(C24:0)	0.24 ± 0.01 a	0.08 ± 0.01 d	0.12 ± 0.01 c	0.15 ± 0.01 b	0.20 ± 0.01 ab
(C24:1)	0.69 ± 0.02 a	ND e	0.19 ± 0.01 d	0.32 ± 0.01 c	0.52 ± 0.01 b
∑SFA	11.85 ± 0.01 e	19.31 ± 0.01 a	17.17 ± 0.01 b	15.22 ± 0.01 c	13.21 ± 0.01 d
∑UFA	85.83 ± 0.01 a	80.55 ± 0.01 e	82.20 ± 0.01 d	83.65 ± 0.01 c	84.97 ± 0.01 b
∑MUFA	37.47 ± 0.09 e	66.58 ± 0.16 a	60.31 ± 0.45 b	52.10 ± 0.07 c	44.42 ± 0.05 d
∑PUFA	48.36 ± 0.17 a	13.97 ± 0.40 e	21.89 ± 0.11 d	31.55 ± 0.01 c	40.55 ± 0.17 b
PUFA/SFA	4.08 ± 0.05 a	0.72 ± 0.01 e	1.27 ± 0.03 d	2.07 ± 0.05 c	3.07 ± 0.05 b
ω3	26.91 ± 0.11 a	0.51 ± 0.01 e	6.62 ± 0.02 d	13.91 ± 0.02 c	20.89 ± 0.01 b
ω6	21.42 ± 0.02 a	13.44 ± 0.36 e	15.25 ± 0.07 d	17.58 ± 0.01 c	19.57 ± 0.04 b
ω6/ω3	0.79 ± 0.01 e	26.35 ± 0.02 a	2.30 ± 0.01 b	1.26 ± 0.01 c	0.93 ± 0.01 d

SFA saturated fatty acids, MUFA monounsaturated fatty acids, PUFA polyunsaturated fatty acids, UFA unsaturated fatty acids, ND: not detected. The measurements were conducted in three replicates and the mean values along with standard deviations are provided. If the table contains identical superscripts, it indicates that the values are not significantly different ($p<0.05$). The Analysis of Variance (ANOVA) was used for the statistical comparison of obtained result means, and Duncan's multirange test at the alpha level of 5% is used to determine critical values for comparisons between means. All statistical analyses were performed using SPSS software.

Nutritional Properties

The nutritional value of CO, VOO, and their blends was evaluated by analyzing several nutritional indexes, including AI, TI, HH, PUFA: SFA, and ω6/ω3 ratio. The FA composition of foods can be used to gain an understanding of their nutritional value through the use of these parameters. The FA profile of these mixed oils has been shown to have positive effects on nutrition and may help prevent diseases such as cardiovascular complications and cancer [30]. AI and TI parameters have the potential to serve as indicators or risk factors for heart diseases.

The nutritional sources with low AI and TI are beneficial in avoiding the risk of cardiovascular problems. The AI values for CO, CO: VOO (75:25), CO: VOO (50:50), CO: VOO (25:75) and VOO were 0.1, 0.12, 0.15, 0.17, and 0.2, respectively. AI was accomplished lower than one, not surpassing 0.2 for all five samples. As illustrated, blending CO with VOO caused a slight increase in the AI value. As shown in the results, enhancing the VOO level in blends led to a significant reduction in TI in the formulated samples ($p<0.05$). Therefore, it was shown that these blended oils had a balanced and desirable FA profile. Furthermore, the cholesterol content of the human body is inversely associated with total PUFA. The FA composition of CO was mostly composed of PUFA. A low PUFA: SFA ratio in the daily diet (below 0.45) can increase the risk of promoting blood cholesterol levels [31]. In the present work, the PUFA: SFA ratio in all of the samples was very high. This ratio notably increased by CO level enhancement in blends for the formulated samples ($p<0.05$). As a result, the addition of CO to VOO had a positive and beneficial effect on the FA content.

It led to an SFA reduction in the blends (19.31% (VOO) to 11.85% (CO)). PUFA: SFA ratios in 25, 50, and 75% CO were 1.27, 2.07, and 3.07, respectively. The HH index suggests that the FA composition affects cholesterol metabolism, and a high HH parameter is considered significant nutritionally. HH parameter of CO with VOO blends was generally higher than VOO alone. HH values in the treatments containing 25, 50 and 75% CO were 5.7, 6.57, and 7.96, respectively. The higher HH and lower AI and TI, the healthier the food source is [32].

It is very important to include oils and oilseeds in daily diet for maintaining optimal health because they have rich content of essential FAs and bioactive compounds. It is also crucial to maintain a balanced ratio of omega-6 and omega-3 FAs for overall health, and therefore it should be prioritized in one's daily diet [32]. The modern approach to nutrition recognizes the importance of maintaining a balanced ratio of omega-6 to omega-3 FAs, but processed food manufacturers tend to avoid using fats that are high in alpha-linolenic acid (an omega-3 FA) in their products to minimize the risk of oxidation and prolong the shelf life of the processed foods [33]. An ideal proportion of omega-6 to omega-3 FAs, which ranges from 4:1 to 1:1, has been deemed effective in preventing and treating different illnesses. However, the ratio of these FAs in different foods varies widely. For example, the ratio of omega-6 to omega-3 FAs in CO is 0.7, while in VOO, it is 26.3 [1]. The significantly lower ratio of ω6:ω3 FAs for CO compared to VOO can be attributed to its high level of linolenic acid. On the other hand, when VOO oil is added to other oils, the resulting blends can improve the omega-6 to omega-3 ratio. For instance, the ratios of the blended oils containing 25%, 50%, and 75% CO oil were 2.3, 1.2, and 0.9, respectively, indicating a significant improvement in the ratio. The nutritional parameters utilized to assess the quality of these created oils indicate that they possess satisfactory nutritional characteristics and may offer advantageous health effects.

Tocopherol

The presence of tocopherols in vegetable oils is recognized for its ability to hinder the oxidation of PUFA and improve the oil's resistance to oxidative damage. Additionally, tocopherols are antioxidants localized in the membrane of human cells. Research studies in populations have indicated that people, who consume lower amounts of antioxidants, including vitamin E, may have a higher likelihood of developing certain types of cancer and atherosclerosis [34]. The tocopherol profile of the oils might affect oxidative stability. It can be concluded that levels of tocopherols found in both CO and VOO may improve oil stability against oxidation.

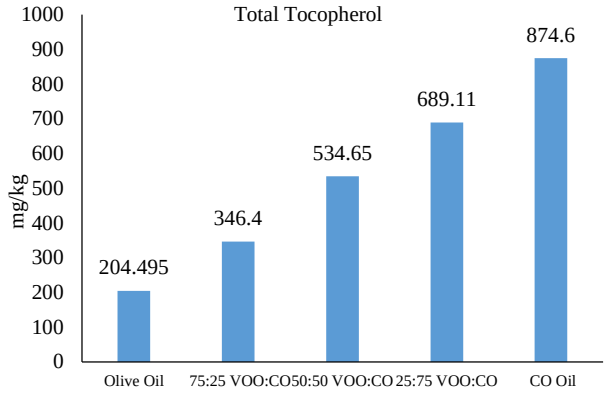

Fig. 1 The measurements were conducted in triplicate. The Analysis of Variance (ANOVA) was used for the statistical comparison of the obtained mean results, and Duncan's multiple range test at the alpha level of 5% was used to determine critical values for comparisons between means.

Figure 1 illustrates the corresponding data. It shows that CO had a high concentration of total tocopherols (874.6 mg/kg), which consisted of 10.82 mg/kg oil of α-tocopherol, 849.5 mg/kg oil of γ-tocopherol, and 14.27 mg/kg oil of δ-tocopherol. Total tocopherol content was found to be equal to 874.6, 204.495, 689.11, 534.65, 346.4mg/kg and in CO, VOO, and their blends samples (25:75, 50:50 and 75:25 VOO: CO) respectively. The blend of CO and VOO in a ratio of 75:25 showed the highest amount among all the oil blends. In the short form, here are the results, Tocopherols amount in the blends decreased following the order CO>CO75:VOO25>CO 50: VOO50>CO25:VOO75>VOO. Moreover, CO was found to have more □-tocopherol, while VOO had more levels of α-tocopherol.

DPPH

The antioxidant capacities of various vegetable oils were assessed using the DPPH assay. As illustrated in Figure 2, an increased proportion of Camelina oil resulted in a notable decrease in DPPH levels. The findings suggest that the incorporation of Camelina oil with virgin olive oil (VOO) enhanced the sample absorbance, and the resulting curves exhibited significant differences among the oil samples. Specifically, Figure 2 demonstrates that the percentage of DPPH radicals associated with Camelina oil was measured at 21.7%, indicating the lowest antioxidant capacity, whereas the highest antioxidant capacity was observed in VOO, at 89.1%.

Total Phenols Content

The level of phenols present in oils is a significant determinant of oil quality, as it directly affects its color and ability to resist oxidation. This, in turn, can enhance oil shelf life. Figure. 3 illustrates that the total phenol content was 32.86, 128.18, 93.86, 76.55, and 52.45 ppm as gallic acid in CO, VOO, and their respective blend samples (75:25, 50:50, and 25:75 VOO: CO). The total phenol content was significantly higher ($P<0.05$) in VOO, with a value of 128.18 ppm gallic acid/kg oil. This was 3.9 times greater than the content found in CO (32.86 ppm gallic acid/kg oil) and all other blends. Furthermore, in Figure 3, it is evident that blending CO with VOO led to a total phenol content that ranged from 52.45 to 93.86 ppm gallic acid/kg oil.

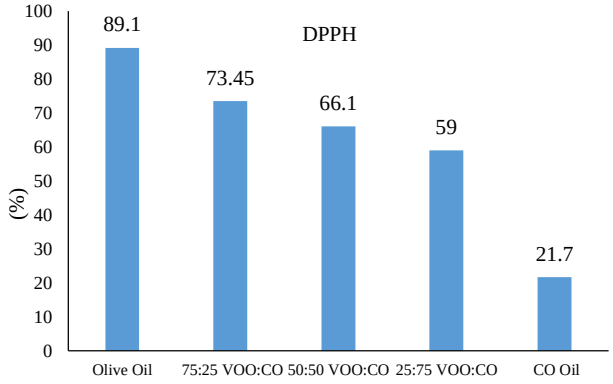

Fig. 2 The measurements were conducted in triplicate. The Analysis of Variance (ANOVA) was used for the statistical comparison of the obtained mean results, and Duncan's multiple range test at the alpha level of 5% was used to determine critical values for comparisons between means.

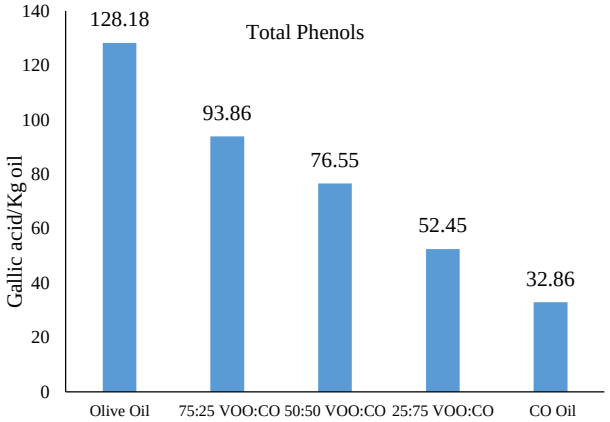

Fig. 3 The measurements were conducted in triplicate. The Analysis of Variance (ANOVA) was used for the statistical comparison of the obtained mean results, and Duncan's multiple range test at the alpha level of 5% was used to determine critical values for comparisons between means.

Oxidative Stability

Figure. 4 shows Rancimat induction time (IT) at 110°C for VOO, CO, and their binary blends with 25%, 50%, and 75% of VOO (w/w). The stability of oxidation is mainly affected by the composition of FAs and the existence of bioactive elements like tocopherols, sterols, polar lipids, metal ions, and hydroperoxide levels. The outcomes of induction periods at 110 °C for CO, CO: VOO (75:25), CO: VOO (50:50), CO: VOO (25:75), and VOO were 2.77, 3.9, 4.92, 6.7, and 8.94 h, respectively. The findings showed that CO had the shortest induction period, followed by the blended oils, and lastly VOO. However, there were significant variations between the samples.

Unsaponifiable Matter

In cold-pressed (CO) and virgin oils (VOO), unsaponifiable matter plays a more significant role compared to other oils, which

includes terpenic alcohols, hydrocarbons, tocopherols, sterols, and other phenolic compounds. Unsaponifiable matter varied significantly ($p \leq 0.05$) among different oil blends. According to Figure. 5, the oil blend with the highest unsaponifiable matter was CO at 1.42%, while the lowest USM was observed in the 50:50 blend of CO and VOO, which recorded 0.79%.

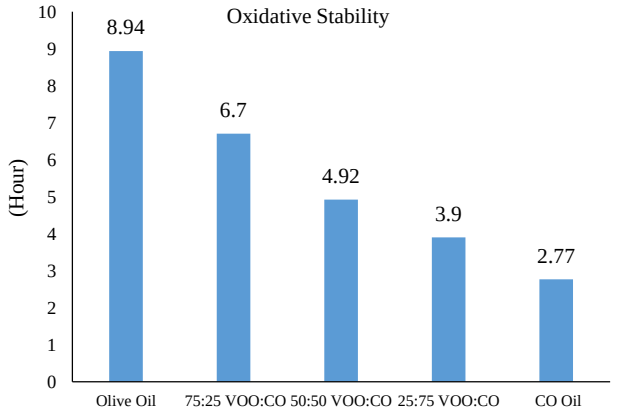

Fig. 4 The measurements were conducted in triplicate. The Analysis of Variance (ANOVA) was used for the statistical comparison of the obtained mean results , and Duncan's multiple range test at the alpha level of 5% was used to determine critical values for comparisons between means.

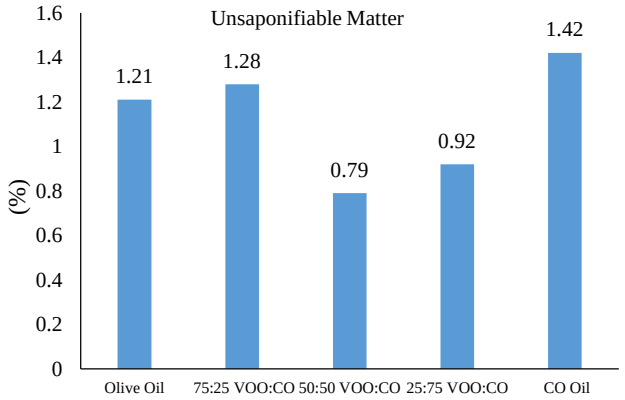

Fig. 5 The measurements were conducted in triplicate. The Analysis of Variance (ANOVA) was used for the statistical comparison of the obtained mean results, and Duncan's multiple range test at the alpha level of 5% was used to determine critical values for comparisons between means.

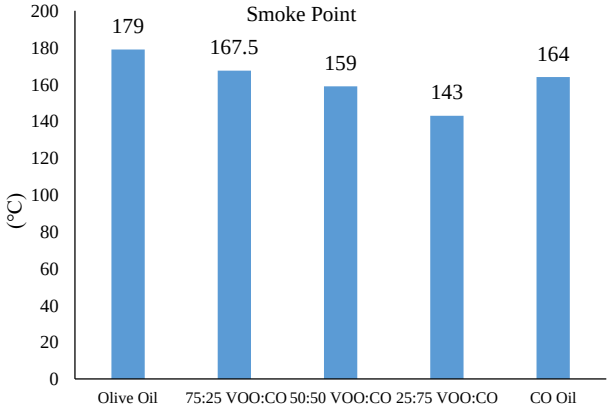

Fig. 6 The measurements were conducted in triplicate. The Analysis of Variance (ANOVA) was used for the statistical comparison of the obtained mean results, and Duncan's multiple range test at the alpha level of 5% was used to determine critical values for comparisons between means.

Smoke Point

The smoke point refers to the minimum temperature at which heated oil or fat generates a consistent bluish smoke. In this study, all the blended oils had a minimum smoke point of 150°C except CO/VOO at a ratio of 75/25 (143°C). Also, VOO had a more favorable smoke point than CO with a difference of 15°C. It is necessary to state that the smoke points of CO mixed with VOO at different ratios were not more proper than CO alone. In other words, as the percentage present of VOO increases, the smoke point also does not necessarily improve.

Precisely, the smoke point was 143, 159, and 167.5 °C in 25%, 50%, and 75% VOO blends, respectively. As a result, a linear relationship was observed between VOO percentages vs. the smoke point, even though there were no notable distinctions in the smoke points of the samples (Fig. 6). Consequently, the addition of VOO to CO positively affects smoke point of the blend compared to CO alone.

CONCLUSION

Herein, the mixture of vegetable oils was shown to be a successful tool to modify the nutritional and functional values of oils. This study possesses the potential to aid the food industry in obtaining the most economical possible oil blends, eligible nutrition value edible oil as well as desirable physicochemical characteristics. Blending CO with VOO formed a beneficial nutritional impact with enhanced stability in formulated oils. The present data illustrated that VOO had a higher content of oleic acid and lower content of linoleic and linolenic acid than CO. Blended oils (CO: VOO) had favorable nutritional parameters, comprising AI, TI, HH, PUFA: SFA, and ω6:ω3 ratio. These results indicated that incorporating CO with VOO can present functional oil with an acceptable ω6:ω3 ratio and positive amounts of bioactive compounds. VOO contains a higher amount of total polyphenols (128.18 mg gallic acid per 100 g oil) compared to CO (32.86 mg GAE per 100 g oil). Nevertheless, a combination of CO with the optimum value of VOO increased the quality and oxidative stability of CO, because VOO is known as a rich source of phenolic compounds and MUFA. Additionally, oxidative stability parameters illustrated that the oil mixtures had favorable stability. The Rancimat outcomes demonstrated that the ratio of 25/75 (CO: VOO) is a suitable candidate for cooking oil, while 50/50 and 75/25 (CO: VOO) ratios can be employed as salad oils.

Mixing various ratios (25, 50, and 75% v/v) of VOO with CO supplies betterment in antioxidant potential. Regarding the advantages and disadvantages of single oil, mixed oils are even to single oil and in some characteristics such as shelf-life stability and nutritional value more proper than single oil for cooking aims. The study found that a combination of CO and VOO at 50/50 (CO: VOO) and 25/75 (VOO: CO) levels had the most favorable quality characteristics. Nevertheless, when considering stability and cost-effectiveness, these blends were deemed superior to other blends.

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