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## CHAPTER 3

# Chemical composition and properties of vegetable oil blends

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### Abstract

Vegetable oils are widely used in food formulations due to their essential role as a source of fat and energy for the human body, as well as their content of vitamins and minerals. The addition of vegetable oils to foods not only improves flavor and texture but also increases the nutritional value of various products. These oils are produced by a variety of methods, typically involving mechanical pressing or extraction processes. The composition of vegetable oils consists primarily of fatty acids, which can be classified as saturated, monounsaturated, and polyunsaturated fats.

The balance of fatty acids plays a critical role in human health, as an optimal ratio of dietary fats is required for various metabolic processes. However, no single vegetable oil provides a perfectly balanced fatty acid profile. Therefore, blending oils in specific proportions can help to achieve a more balanced composition of dietary fats. Such blended oils can be used in a wide range of culinary applications, including cooking, frying, and baking, and offer a versatile and nutritious alternative to traditional oils.

In this study, four vegetable oil blends with a balanced composition of polyunsaturated fatty acids (omega-3:omega-6) were developed: olive oil – rapeseed oil – sunflower oil; linseed oil – olive oil – sunflower oil; corn oil – olive oil – rapeseed oil; and corn oil – linseed oil – olive oil. The acid value, peroxide value, and iodine value of the individual oils and their blends were studied to assess their quality and stability. The acid value of the developed vegetable oil blends ranged from 0.30 to 0.56 mg KOH/g, which were within the acceptable limit of 0.6 mg KOH/g recommended by CODEX STAN 210-1999. Similarly, the peroxide value of the vegetable oil blends varied from 2.3 to 2.9 mmol O<sub>2</sub>/kg, which were also well below the acceptable limit of 7 mmol O<sub>2</sub>/kg for vegetable oils. The iodine value of the blends ranged from 112 to 145 g I<sub>2</sub>/100 g, reflecting the degree of unsaturation of the oils.

In addition, the chemical composition of the individual vegetable oils and their blends was analyzed, providing further insight into the properties and benefits of using such oil blends in food production. The results confirm that these vegetable oil blends not only offer a favorable fatty acid balance, but also maintain a stable quality, making them suitable for a variety of culinary applications while promoting health-conscious dietary choices.

### **Keywords**

Corn oil, linseed oil, olive oil, rapeseed oil, sunflower oil, fatty acid composition, alpha-linolenic acid, linoleic acid.

## **3.1 Introduction**

Vegetable oils are important nutritional components that provide essential fatty acids, aid in the absorption of fat-soluble vitamins, and serve as a source of energy for consumers. They also contain vitamins E and K, iron, potassium, calcium, phosphorus, and other minerals, as well as fatty acids [1]. In addition, as an ingredient, vegetable oil can influence the texture, stability, and sensory properties of foods [2]. Consumers prefer cold-pressed oils as this process results in less alteration of the bioactive components in the oil compared to refined oils [3]. Despite the wide range of vegetable oils available on the market, none of them meet the recommended fatty acid ratio.

Fats are the primary source of energy for humans. They influence the quality of food, play a crucial role in the formation of taste and aroma sensations, and also contribute to the feeling of satiety. According to recommendations [4], fat intake should provide 20–35% of the total energy required for the normal functioning of an adult human body. The biological value of fat is determined by its fatty acid composition and the ratio of saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids. The World Health Organisation (WHO) recommends a balanced proportion of dietary fats (SFA:MUFA:PUFA) of 1:1.5:1, as well as a ratio of omega-3 fatty acid (alpha-linolenic acid) to omega-6 fatty acid (linoleic acid) of 1:5–10 [4, 5]. Omega-3 and omega-6 fatty acids are essential because the human body cannot produce them, and they must be obtained from the diet [6].

Most vegetable oils (rapeseed, soybean, corn, sunflower) are sources of omega-6 fatty acid in the form of linoleic acid and have a low content of omega-3 fatty acid [7]. Lipids in edible oils are sensitive to autoxidation and photo-oxidation during processing and storage, leading to the development of undesirable flavours, the formation of toxic compounds, and a reduction in the nutritional value of the food

product [8]. Vegetable oils have a high biodegradability (95%) [9], a high flash point of 275–320°C [10], and a smoke point of 175–255°C [11].

Vegetable oils do not have an ideal fatty acid profile (**Table 3.1**), which is why blending is an effective way to balance their fatty acid composition. This approach makes it possible to create complex systems from high-quality vegetable oils, enriching them with fat-soluble vitamins, phospholipids, and spices, and enabling them to be used in the manufacture of fatty foods. Blended oils can be consumed directly as food and used as a fat base for the development of functional foods. Blended oils, produced in Ukraine and other countries, are classified into vitaminized blended oils with a balanced PUFA composition, stabilized with synthetic components to prevent oxidative spoilage, and vitaminized blended oils enriched with biologically active substances (rosehip oil, pumpkin oil, pine nut oil, and linseed oil), which do not have a balanced PUFA composition.

**Table 3.1** Fatty acid composition of vegetable oils

Vegetable oils	Mean, %			References
	SFA	MUFA	PUFA	
Almond oil	5.77	67.75	26.58	R. Yang et al. [12]
Coconut oil	92.92	5.84	1.28	K. Chowdhury et al. [13]
Corn oil	15.39	31.34	52.82	R. Yang et al. [12]
Grape seed oil	11.07	17.07	71.80	R. Yang et al. [12]
Linseed oil	12.71	23.54	63.20	R. Yang et al. [12]
Mustard oil	15.94	49.57	36.62	K. Chowdhury et al. [13]
Olive oil	16.16*	67.33*	14.84*	B. Marongui et al. [14]
Palm oil	46.34	41.46	11.84	K. Chowdhury et al. [13]
Pumpkin seed oil	18.84	28.25	52.92	R. Yang et al. [12]
Rapeseed oil	7.00	61.00	32.00	L. Sakhno [15]
Soybean oil	18.26	23.28	57.86	K. Chowdhury et al. [13]
Sunflower oil	8.80	31.50	59.50	V. Kostik et al. [16]
Walnut oil	8.38	18.24	68.89	R. Yang et al. [12]

Note: \*calculated by the authors

The typical Western-type diet is characterized by 5 to 15 times higher intake of linoleic acid (LA) than alpha-linolenic acid (ALA) [17]. This is because consumers' diets often contain high levels of sunflower, olive, and corn oils, which are rich in LA,

and virtually no foods rich in ALA, such as linseed and rapeseed oils (**Table 3.2**). At the same time, ALA is the main source of omega-3 PUFAs in the diet of people who do not regularly consume oily fish [18].

**Table 3.2** The content of ALA and LA in vegetable oils

Vegetable oils	Mean, %		ALA: LA ratio	References
	ALA	LA		
Corn oil	1.0	57.0	1:57	L. Sakhno [15]
Linseed oil	51.5*	15.9*	1:0.3	M. Nykter et al. [19]
Olive oil	1.0	9.0	1:9	L. Sakhno [15]
Rapeseed oil	11.0	21.0	1:1.9	L. Sakhno [15]
Sunflower oil	1.0	71.0	1:71	L. Sakhno [15]

Note: \*calculated by the authors for commercial linseed oil

It is important to develop blended vegetable oils with a balanced fatty acid composition in line with WHO recommendations. These blends can be consumed by adding them to various foods, especially in the form of salad dressings.

## 3.2 Physicochemical and sensory properties of vegetable oils

Each type of vegetable oil has its own unique chemical composition, physical and nutritional properties, offering specific benefits and health effects [20]. Therefore, consumers can choose different types of vegetable oil to suit their individual needs.

### 3.2.1 Corn oil

Corn oil belongs to the group of vegetable oils with a high content of linoleic acid (more than 52.0%) and oleic acid (30.5%), but it contains only 1.0% of linolenic acid [21]. Corn oil contains approximately 60% PUFAs, 25% MUFAs, and 15% SFAs, as well as a total of 1.3–2.3% phytosterols, tocopherols, tocotrienols, and squalene [21]. The squalene content of corn oil ranges from 6.8 to 256.8 mg per 100 g, and the  $\beta$ -carotene content is approximately 0.1 mg/kg [20]. The total phenolic content of corn oil is 12.6–53.6 mg/kg [20]. The physical properties of corn oil

are as follows: density 914 g/L, viscosity 35.4 cSt, flash point 259°C and higher heating value 39.66 MJ/kg [22]. Corn oil has a pleasant smell and taste. Its color ranges from pale yellow to reddish brown. Corn oil is important for human health due to its unique characteristics and nutritional properties [23].

### 3.2.2 Linseed oil

Linseed oil is one of the richest sources of omega-3 PUFAs [24]. In the health food market, linseed oil is becoming increasingly popular as a functional food due to its health benefits. Due to its beneficial properties, linseed oil is used not only in functional food products but also in the production of nutraceutical, pharmaceutical, and cosmetic products [24]. Linseed oil has a fatty acid profile with a low content of saturated fats (9%), a moderate content of MUFAs (about 18%), and a high content of PUFAs (about 73%), with approximately 16% of fatty acids being omega-6 (mainly LA) and 57% being omega-3 (ALA) [25]. The high ALA content leads to oxidative instability of linseed oil [26]. Due to its instability, linseed oil is not recommended for sole use in food production [27]. The squalene content of linseed oil is 2.4–83.0 mg/100 g [20]. The carotenoid content of linseed oil is as follows (mg/kg):  $\beta$ -carotene 34.9–76.9, lutein 11.6, and zeaxanthin 1.1 [20]. The total phenolic content of linseed oil is 4.0–3073.0 mg/kg [20]. The physical properties of linseed oil are as follows: density 921 g/L, viscosity 27.2 cSt, flash point 247°C and higher heating value 39.5 MJ/kg [22]. Linseed oil is a colorless to yellowish oil with a light hay-like smell, a faint fishy aroma, and a bitter taste.

### 3.2.3 Olive oil

Olive oil is known for its health benefits due to its significant content of functionally active compounds, including phenolic compounds (tyrosol, oleocanthal, oleuropein, hydroxytyrosol, and oleuropein aglycone) and biologically active carotenoids [28]. The carotenoid content of olive oil is as follows (mg/kg):  $\beta$ -carotene 36.0, lutein 0.8–4.4, zeaxanthin 0.8, lycopene 0.8, and  $\alpha$ -carotene 3.6 [20]. The squalene content of olive oil ranges from 153.4 to 747.4 mg per 100 g [20]. The total phenolic content of olive oil is 23.0–2180.0 mg/kg [20]. The physical properties of olive oil are as follows: density 918 g/L, viscosity 29.8 cSt, flash point 231°C and higher heating value 39.5 MJ/kg [22]. Olive oil is mainly composed of triacylglycerols (98%) and a number of substances including free fatty acids, phenols, tocopherols, sterols,

phospholipids and volatile compounds [29]. Oleic acid accounts for 60–80% of the total fatty acid composition of olive oil [30]. Olive oil has a golden color with various shades of green.

### 3.2.4 Rapeseed oil

Rapeseed oil is the third most popular edible oil in the world due to its high nutritional value, mainly due to its high content of unsaturated fatty acids, especially PUFAs [31]. In addition to unsaturated fatty acids, rapeseed oil contains functional components such as vitamin E, flavonoids, squalene, carotenoids, glucoraphanin, sterols, phospholipids, and ferulic acid, all of which have health benefits [31]. The squalene content of rapeseed oil is 2.1–12.5 mg/100 g [20]. The carotenoid content of rapeseed oil is as follows (mg/kg):  $\beta$ -carotene 6.0–18.8, lutein 32.6–95.0, and zeaxanthin 1.2 [20]. The total phenolic content of rapeseed oil is 10.3–1654.5 mg/kg [20]. The physical properties of rapeseed oil are as follows: density 912 g/L, viscosity 37.3 cSt, flash point 258°C and higher heating value 39.52 MJ/kg [22]. More than one hundred aroma-active compounds have been identified in rapeseed oil, including aldehydes, ketones, acids, esters, alcohols, phenols, pyrazines, furans, indole, pyridines, pyrrolines, thiazoles, thiophene, alkenes and others, which contribute to its flavor [32]. The color of rapeseed oil varies from yellow to brown, depending on the production method. Rapeseed oil has a very mild flavor, but heating this oil can lead to the formation of off-flavors, often characterized by a fishy smell.

### 3.2.5 Sunflower oil

Sunflower oil is the main type of vegetable oil produced in Ukraine. It is widely used as a food product in its natural form in cooking. Sunflower oil has high nutritional value due to its high LA content [32], as well as its elevated levels of vitamin E and phytosterols compared to other oils [28]. The tocopherol content of sunflower oil ranges from 270 to 1240 mg/kg, which increases its nutritional value [33]. Sunflower oil contains 5.3–27.1 mg/100 g of squalene and 11.6–12.4 mg/kg of lutein [20]. The total phenolic content of sunflower oil ranges from 4.8 to 1920.0 mg per kg [20]. The physical properties of sunflower oil are as follows: density 916 g/l, viscosity 33.9 cSt, flash point 262°C and higher heating value 39.59 MJ/kg [22]. Unrefined sunflower oil has a light yellow color, while refined oil has a pale yellow hue. It has a pleasant flavor and aroma which can be easily removed by deodorization.

### 3.3 Materials and methods

#### 3.3.1 Materials

Samples of refined olive oil (OO), rapeseed oil (RO), and sunflower oil (SO), as well as unrefined corn oil (CO), and linseed oil (LO), were analyzed. The vegetable oils were purchased from a local supermarket (Lutsk, Ukraine).

The blended oil samples were prepared by mixing three types of vegetable oils in the required proportions. The ratio of vegetable oils in the blend was calculated using the following Equations, taking into account the recommended ratios of omega-3:omega-6 (1:10) and MUFA:PUFA (1.5:1) in foods [4, 5]:

$$x_1 + x_2 + x_3 = 100, \quad (3.1)$$

$$\frac{a_1x_1 + a_2x_2 + a_3x_3}{b_1x_1 + b_2x_2 + b_3x_3} = \frac{1}{10}, \quad (3.2)$$

$$\frac{c_1x_1 + c_2x_2 + c_3x_3}{d_1x_1 + d_2x_2 + d_3x_3} = \frac{1.5}{1}, \quad (3.3)$$

where  $x_1$ ,  $x_2$ , and  $x_3$  are the contents of the three vegetable oils in the blended oil (%);  $a_1$ ,  $a_2$ , and  $a_3$  are the contents of ALA (omega-3) in  $x_1$ ,  $x_2$ , and  $x_3$  vegetable oils, respectively (%);  $b_1$ ,  $b_2$ , and  $b_3$  are the contents of LA (omega-6) in  $x_1$ ,  $x_2$ , and  $x_3$  vegetable oils, respectively (%);  $c_1$ ,  $c_2$ , and  $c_3$  are the contents of MUFAs in  $x_1$ ,  $x_2$ , and  $x_3$  vegetable oils, respectively (%);  $d_1$ ,  $d_2$ , and  $d_3$  are the contents of PUFAs in  $x_1$ ,  $x_2$ , and  $x_3$  vegetable oils, respectively (%).

The results of the calculation of the content of vegetable oils in the blend are shown in **Table 3.3**.

**Table 3.3** Content of vegetable oils in the blend

Oil blend samples	Vegetable oil content, %				
	CO	LO	OO	RO	SO
OBS1	-	-	45.15	22.00	32.85
OBS2	-	4.01	60.62	-	35.37
OBS3	40.77	-	38.13	21.10	-
OBS4	43.78	3.83	52.39	-	-

Taking into account the required fatty acid composition in the oil blends, four samples of oil blends were defined, namely: oil blend OBS1 (OO-RO-SO); oil blend

OBS2 (LO–OO–SO); oil blend OBS3 (CO–OO–RO); oil blend OBS4 (CO–LO–OO). The recommended ratios of omega-3:omega-6 (1:10) and SFA:PUFA (1.5:1) were maintained in all oil blend samples (Table 3.4).

**Table 3.4 Content and ratio of MUFAs and PUFAs in samples of vegetable oil blends**

Oil blend samples	Content of PUFAs, %		ALA:LA ratio	Content, %		MUFA:PUFA ratio
	ALA	LA		MUFA	PUFA	
OBS1	3.20	32.00	1.0:10.0	52.81	35.21	1.5:1.0
OBS2	3.11	31.10	1.0:10.0	51.44	34.29	1.5:1.0
OBS3	3.11	31.10	1.0:10.0	51.32	34.21	1.5:1.0
OBS4	3.02	30.24	1.0:10.0	49.90	33.27	1.5:1.0

*Note: to calculate the oil ratio in the blend, the PUFA content of the vegetable oils was considered equal to the sum of the ALA and LA content (Table 3.2), while the MUFA content of the vegetable oils was taken from the data in Table 3.1*

### 3.3.2 Methods

#### 3.3.2.1 Acid value

The acid value of vegetable oils is the number of milligrams of potassium hydroxide (KOH) necessary to neutralize the free acids presented in 1 g of test sample. The acid value of vegetable oils and their blends was determined by the method according to ISO 660:2020 "Animal and vegetable fats and oils – Determination of acid value and acidity". The oil or blend sample was dissolved in a suitable solvent mixture, and the acids present are titrated with an ethanolic solution of potassium hydroxide.

#### 3.3.2.2 Peroxide value

The peroxide value of vegetable oils and their blends was determined by the method according to ISO 3960:2017 "Animal and vegetable fats and oils – Determination of peroxide value – Iodometric (visual) endpoint determination". The oil or blend sample was dissolved in isooctane and glacial acetic acid, and potassium iodide was added. The iodine liberated by the peroxides was determined visually with a starch indicator and a sodium thiosulfate standard solution. The endpoint of the titration was determined visually. The peroxide value was expressed in millimoles (mmol) of active oxygen per kilogram of oil (mmol O<sub>2</sub>/kg).

### 3.3.2.3 Iodine value

The iodine value of vegetable oils and their blends was determined by the method according to ISO 3961:2018 "Animal and vegetable fats and oils – Determination of iodine value". The oil or blend sample was dissolved in a solvent, and Wijs reagent was added. After a specified time, potassium iodide and water were added, and the liberated iodine was titrated with sodium thiosulfate solution. The iodine value was calculated in grams per 100 g of vegetable oil or blend using equation

$$w_I = \frac{12.69c(V_1 - V_2)}{m}, \quad (3.4)$$

where  $c$  is the concentration of the sodium thiosulfate solution (mol/l);  $V_1$  is the volume of sodium thiosulfate solution used for the blank test (ml);  $V_2$  is the volume of sodium thiosulfate solution used for the determination (ml);  $m$  is the mass of the vegetable oil or blend sample (g).

### 3.3.2.4 Fatty acid content

The fatty acid content of vegetable oils and their blends was determined by gas chromatography – mass spectrometry (GC–MS) using a Shimadzu GCMS2030-QP2020NX gas chromatograph. Helium was used as carrier gas at a flow rate of 1.18 mL/min. The temperature of the injector was 250°C. The temperature program was held at 80°C for 1 min, increased to 250°C at 15°C/min and held for 8 min, and increased to 310°C at 20°C/min and held for 10 min. The mass spectrometric conditions were ion source and interface temperatures of 250°C and 300°C, respectively; the measurements were conducted in the full scan mode (40–900 m/z).

The method was performed according to ISO 12966-1 "Animal and vegetable fats and oils – Gas chromatography of fatty acid methyl esters – Part 1: Guidelines on modern gas chromatography of fatty acid methyl esters". The Shimadzu GC–MS Solution Analysis software was used to process the collected raw data, including peak area integration and normalization, to obtain a data matrix containing sample information and relative intensities of the compounds [34]. The NIST/EPA/NIH mass spectrometer library was used to identify the resolved components.

### 3.3.2.5 Statistical analysis and calculations

All data reported as mean  $\pm$  standard deviation (SD). Statistical analysis and calculations were conducted using the Mathcad 14 software.

## 3.4 Results and discussion

The highest acid values were found in unrefined linseed oil ( $0.86 \pm 0.04$  mg KOH/g) and unrefined corn oil ( $0.84 \pm 0.05$  mg KOH/g) (Table 3.5). Refined oils had acid values ranging from 0.28 to 0.56 mg KOH/g, which is 33–67% lower than in unrefined oils. Among refined oils, the highest acid value was found in rapeseed oil ( $0.56 \pm 0.02$  mg KOH/g). Olive and sunflower oils had the same acid value of 0.28 mg KOH/g.

According to N.A. Fakhri and H.K. Qadir [35], the acid values of vegetable oils were as follows: CO – 0.51 mg KOH/g; OO – 3.45–18.93 mg KOH/g; RO – 0.65 mg KOH/g; SO – 0.52–0.80 mg KOH/g. The acid value of linseed oil, according to [36], ranged from 2.10 to 3.04 mg KOH/g. Therefore, the acid value of vegetable oils can vary widely depending on the raw material properties and the oil production method.

The acid value is a crucial parameter for assessing the quality of the vegetable oil [37]. A lower acid value indicates better oil quality and freshness, as well as its stability over time, providing protection against rancidity and peroxidation [38]. Vegetable oils with an acid value above 3 mg KOH/g are considered unfit for human consumption in some countries [37]. According to the Standard for Named Vegetable Oils (CODEX STAN 210-1999), the maximum acceptable oil acid value is 0.6 mg KOH/g for refined oils and 4.0 mg KOH/g for cold-pressed and virgin oils.

**Table 3.5 Acid value, peroxide value and iodine value of vegetable oils**

Parameter	Vegetable oil				
	CO	LO	OO	RO	SO
Acid value, mg KOH/g	$0.84 \pm 0.05$	$0.86 \pm 0.04$	$0.28 \pm 0.03$	$0.56 \pm 0.02$	$0.28 \pm 0.01$
Peroxide value, mmol O <sub>2</sub> /kg	$3.4 \pm 0.1$	$4.6 \pm 0.1$	$2.0 \pm 0.1$	$3.8 \pm 0.0$	$2.5 \pm 0.1$
Iodine value, g I <sub>2</sub> /100 g	$115 \pm 4$	$172 \pm 5$	$90 \pm 4$	$108 \pm 3$	$128 \pm 4$

The highest peroxide value was found in linseed oil ( $4.6 \pm 0.1$  mmol O<sub>2</sub>/kg), while the lowest peroxide value was observed in olive oil ( $2.0 \pm 0.1$  mmol O<sub>2</sub>/kg) (Table 3.5). Sunflower oil had a peroxide value of  $2.5 \pm 0.1$  mmol O<sub>2</sub>/kg, while corn oil and rapeseed

oil had peroxide values of  $3.4 \pm 0.1$  and  $3.8 \pm 0.0$  mmol  $O_2$ /kg, respectively. The peroxide value is commonly used as an index to monitor the oxidation of vegetable oils and to assess oil quality during processing, storage and marketing [39]. High peroxide values indicate increased levels of oxidative rancidity in vegetable oils and suggest a lack of or low levels of antioxidants [38]. According to R. Vidrih, S. Vidakovič, and H. Abramovič [40], a peroxide value of 10 mmol  $O_2$ /kg was considered the upper limit for unrefined oils, while a peroxide value of 7 mmol  $O_2$ /kg was the upper limit for refined oils.

The iodine value of unrefined vegetable oils ranged from 115 to 172 g  $I_2$ /100 g, while refined oils had values between 90 and 128 g  $I_2$ /100 g (Table 3.5). The highest iodine value was found in linseed oil at  $172 \pm 5$  g  $I_2$ /100 g, while olive oil had the lowest iodine value at  $90 \pm 4$  g  $I_2$ /100 g. According to previous studies [41], the iodine values of vegetable oils were as follows: CO 110.81 g  $I_2$ /100 g; OO 72.00–101.25 g  $I_2$ /100 g; RO 162.86 g  $I_2$ /100 g; SO 118.65–159.55 g  $I_2$ /100 g. The iodine value of linseed oil was found to be between 173.39 and 178.83 g  $I_2$ /100 g by N. Beema et al. [36]. The higher the level of unsaturation, the higher the iodine value and the greater the tendency of the vegetable oil to become rancid through oxidation [38].

The acid value of the developed oil blends ranged from 0.30 to 0.56 mg KOH/g (Table 3.6). The acid value of the blend depended on the vegetable oils contained in it. The higher the content of oils with a higher acid value in the blend, the higher the acid value of the blend itself. The highest acid value ( $0.56 \pm 0.02$  mg KOH/g) was found in the OBS3 blend, which contained corn oil (40.77%), olive oil (38.13%) and rapeseed oil (21.10%) with acid values of 0.84, 0.28, and 0.56 mg KOH/g, respectively. The lowest acid value ( $0.30 \pm 0.03$  mg KOH/g) was found in the OBS2 blend containing olive oil (60.62%), sunflower oil (35.37%) and linseed oil (4.01%) with acid values of 0.28, 0.28 and 0.86 mg KOH/g, respectively. Therefore, the maximum level of 0.6 mg KOH/g recommended by CODEX STAN 210-1999 was not exceeded in any of the oil blends.

**Table 3.6 Acid value, peroxide value and iodine value of vegetable oil blend**

Parameter	Vegetable oil blend			
	OBS1	OBS2	OBS3	OBS4
Acid value, mg KOH/g	$0.31 \pm 0.01$	$0.30 \pm 0.03$	$0.56 \pm 0.02$	$0.53 \pm 0.01$
Peroxide value, mmol $O_2$ /kg	$2.4 \pm 0.1$	$2.3 \pm 0.0$	$2.9 \pm 0.0$	$2.8 \pm 0.1$
Iodine value, g $I_2$ /100 g	$112 \pm 5$	$140 \pm 4$	$114 \pm 5$	$145 \pm 6$

The peroxide value of the oil blends ranged from 2.3 to 2.9 mmol  $O_2$ /kg (Table 3.6). The OBS3 and OBS4 blends had the highest peroxide values of  $2.9 \pm 0.0$  and

$2.8 \pm 0.1$  mmol  $O_2$ /kg, respectively. The peroxide value of the OBS3 blend was attributed to its high content of corn oil (40.77%) and rapeseed oil (21.10%), which had high peroxide values of 3.4 and 3.8 mmol  $O_2$ /kg, respectively. The OBS4 blend also contained a high proportion of corn oil (43.78%) with a high peroxide value, as well as linseed oil (3.83%) with a peroxide value of 4.6 mmol  $O_2$ /kg. The peroxide value of the developed oil blends did not exceed the highest acceptable value recommended by previous studies [40], which was 7 mmol  $O_2$ /kg.

The iodine value of the vegetable oil blends also depended on the composition of the blend and ranged from 112 to 145 g  $I_2$ /100 g (Table 3.6). The highest iodine values were found in the blends OBS2 ( $140 \pm 4$  g  $I_2$ /100 g) and OBS4 ( $145 \pm 6$  g  $I_2$ /100 g). These two blends contained linseed oil, which had the highest iodine value ( $172 \pm 5$  g  $I_2$ /100 g). The OBS1 and OBS3 blends had iodine values of  $112 \pm 5$  and  $114 \pm 5$  g  $I_2$ /100 g, respectively. Olive oil and rapeseed oil had the highest total content in these blends (for OBS1: total OO+RO – 67.15%; for OBS3: total OO+RO – 59.23%). These oils had the lowest iodine values of  $90 \pm 4$  (OO) and  $108 \pm 3$  (RO) g  $I_2$ /100 g.

Table 3.7 shows the results of the determination of the fatty acid content of vegetable oils available on the Ukrainian market. The highest content of saturated fatty acids was found in olive oil (17.35%), and the lowest in rapeseed oil (8.73%). B. Marongui et al. [14] found that the average content of saturated fatty acids in olive oil was 16.16%. According to L. Sakhno [15], rapeseed oil contained 7.0% of saturated fatty acids. In vegetable oils, palmitic acid (5.62–9.25%) and stearic acid (1.98–7.52%) had the highest content among the saturated fatty acids. The content of arachidic acid and behenic acid in the oils was 0.31–0.82% and 0.31–0.98% respectively. Lignoceric acid (0.30%) was only found in corn oil.

The monounsaturated fatty acid content of the analyzed oils ranged from 17.54% to 62.98% (Table 3.7). The highest content of monounsaturated fatty acids was found in rapeseed oil (62.98%) and olive oil (62.40%), while the lowest was in linseed oil (17.54%). According to previous studies, the content of monounsaturated fatty acids in vegetable oils was as follows: linseed oil 23.54% [12], rapeseed oil 61.00% [15], and olive oil 67.33% [14]. Palmitoleic acid was only found in rapeseed oil (0.12%) and sunflower oil (0.08%). The content of oleic acid was ranged from 17.26% (linseed oil) to 62.40% (olive oil). Erucic acid and nervonic acid were only found in corn oil, at 1.80% and 0.46%, respectively. The content of eicosenoic acid in vegetable oils ranged from 0.22% to 3.89%. No eicosenoic acid was found in olive oil.

The highest content of polyunsaturated fatty acids was found in linseed oil (66.83%) and sunflower oil (55.56%) (Table 3.7). Olive oil and rapeseed oil contained the least polyunsaturated fatty acids, with 20.25% and 28.29%, respectively. Linseed oil was a source of alpha-linolenic acid (52.72%), while sunflower oil and corn

oil were sources of linoleic acid, with contents of 55.56% and 47.84%, respectively. No alpha-linolenic acid was found in sunflower oil.

**Table 3.7 Fatty acid content (%) of vegetable oils**

Fatty acid	Vegetable oil				
	CO	LO	OO	RO	SO
<b>SFA</b>					
Palmitic acid (C <sub>16:0</sub> )	7.89	7.37	9.25	5.62	5.87
Stearic acid (C <sub>18:0</sub> )	4.03	7.52	6.74	1.98	4.55
Arachidic acid (C <sub>20:0</sub> )	0.56	0.31	0.38	0.82	0.35
Behenic acid (C <sub>22:0</sub> )	0.82	0.43	0.98	0.31	0.91
Lignoceric acid (C <sub>24:0</sub> )	0.30	ND	ND	ND	ND
<b>Total</b>	<b>13.60</b>	<b>15.63</b>	<b>17.35</b>	<b>8.73</b>	<b>11.68</b>
<b>MUFA</b>					
Palmitoleic acid (C <sub>16:1</sub> )	ND	ND	ND	0.12	0.08
Oleic acid (C <sub>18:1</sub> )	31.60	17.26	62.40	60.94	32.46
Eicosenoic acid (C <sub>20:1</sub> )	3.89	0.28	ND	1.92	0.22
Erucic acid (C <sub>22:1</sub> )	1.80	ND	ND	ND	ND
Nervonic acid (C <sub>24:1</sub> )	0.46	ND	ND	ND	ND
<b>Total</b>	<b>37.75</b>	<b>17.54</b>	<b>62.40</b>	<b>62.98</b>	<b>32.76</b>
<b>PUFA</b>					
ALA	0.81	52.72	1.53	9.08	ND
LA	47.84	14.11	18.72	19.21	55.56
<b>Total</b>	<b>48.65</b>	<b>66.83</b>	<b>20.25</b>	<b>28.29</b>	<b>55.56</b>
ALA:LA ratio	1:59.1	1:0.3	1:12.2	1:2.1	-
MUFA:PUFA ratio	0.8:1	0.3:1	3.1:1	2.2:1	0.6:1

Note: ND - not detected

The ALA:LA ratio in the vegetable oils was as follows: corn oil 1:59.1, linseed oil 1:0.3, olive oil 1:12.2, rapeseed oil 1:2 (**Table 3.7**). Only in olive oil is the ALA:LA ratio close to the recommended 1:5–10 [4, 5]. The ALA:LA ratio found for the vegetable oils studied, particularly olive oil and rapeseed oil, differs somewhat from the ratios reported by other researchers for oils (**Table 3.2**).

The MUFA:PUFA ratio in the vegetable oils was as follows: corn oil 0.8:1, linseed oil 0.3:1, olive oil 3.1:1, rapeseed oil 2.2:1, sunflower oil 0.6:1 (**Table 3.7**). Therefore, this ratio does not correspond to the recommended value of 1.5:1 in any of the vegetable oils studied [4, 5]. The MUFA:PUFA ratios found by researchers in other studies

were as follows: corn oil 0.6:1 [12], linseed oil 0.4:1 [12], olive oil 4.5:1 [14], rapeseed oil 1.9:1 [15], sunflower oil 0.5:1 [16] (Table 3.1). Therefore, the greatest discrepancy in MUFA:PUFA ratio values between the oils studied and those studied by other researchers is observed for olive oil.

The fatty acid composition of the developed vegetable oil blends is shown in Table 3.8. The content of saturated fatty acids in the oil blends ranged from 13.82% to 15.96%. The highest content of saturated fatty acids was found in the samples OBS4 and OBS2, with 15.96% and 15.77%, respectively. This is explained by the high content of olive oil in these blends, 52.39% (OBS4) and 60.62% (OBS2), which had the highest content of saturated fatty acids at 17.35%. The oil blend OBS1 had the lowest content of saturated fatty acids at 13.82%, due to the presence in its composition of sunflower oil (32.85%) and rapeseed oil (22.00%), both of which had a relatively low content of saturated fatty acids, 11.68% and 8.73%, respectively. The oil blends contained the highest levels of palmitic acid (7.51–8.43%) and stearic acid (5.03–6.27%), while the levels of arachidic acid and behenic acid did not exceed 1%.

**Table 3.8 Fatty acid content (%) of vegetable oil blend**

Fatty acid	Vegetable oil blend			
	OBS1	OBS2	OBS3	OBS4
<b>SFA</b>				
Palmitic acid (C <sub>16:0</sub> )	7.51	8.18	8.03	8.43
Stearic acid (C <sub>18:0</sub> )	5.03	6.27	5.03	6.08
Arachidic acid (C <sub>20:0</sub> )	0.47	0.36	0.59	0.46
Behenic acid (C <sub>22:0</sub> )	0.81	0.96	0.83	0.99
<b>Total</b>	<b>13.82</b>	<b>15.77</b>	<b>14.48</b>	<b>15.96</b>
<b>MUFA</b>				
Palmitoleic acid (C <sub>16:1</sub> )	ND	ND	ND	ND
Oleic acid (C <sub>18:1</sub> )	51.98	49.51	49.24	47.01
Eicosenoic acid (C <sub>20:1</sub> )	0.58	0.11	2.00	1.75
Erucic acid (C <sub>22:1</sub> )	ND	ND	0.75	0.81
<b>Total</b>	<b>52.56</b>	<b>49.62</b>	<b>51.99</b>	<b>49.57</b>
<b>PUFA</b>				
ALA	2.69	3.04	2.83	3.18
LA	30.93	31.57	30.70	31.29
<b>Total</b>	<b>33.62</b>	<b>34.61</b>	<b>33.53</b>	<b>34.47</b>
ALA:LA ratio	1:11.5	1:10.4	1:10.8	1:9.8
MUFA:PUFA ratio	1.6:1	1.4:1	1.6:1	1.4:1

Note: ND - not detected

The highest content of monounsaturated fatty acids was found in samples OBS1 (52.56%) and OBS3 (51.99%) (Table 3.8). These samples contained olive oil and rapeseed oil, which had the highest content of monounsaturated fatty acids, 62.40% and 62.98%, respectively. Sample OBS2 had the lowest content of monounsaturated fatty acids (49.62%) because it contained linseed oil and sunflower oil, which had relatively low contents of monounsaturated fatty acids, 17.54% and 32.76%, respectively. All samples had a high content of oleic acid (47.01–51.98%), while the content of eicosenoic acid ranged from 0.11% to 2.00%. Erucic acid was only detected in samples OBS3 (0.75%) and OBS4 (0.81%), while palmitoleic acid was not detected in any of the samples.

The polyunsaturated fatty acid content of the oil blends ranged from 33.53% (OBS3) to 34.61% (OBS2) (Table 3.8). Sample OBS4 had the highest alpha-linolenic acid content (3.18%), while sample OBS1 had the lowest (2.69%). The oil blend OBS2 contained the highest content of linoleic acid (31.57%). At the same time, the alpha-linolenic acid content of the developed oil blends differed by less than 0.5% and the linoleic acid content by less than 1.0%. The ALA:LA ratio in the samples ranged from 1:9.8 to 1:11.5, with the recommended value being 1:10 (used to calculate the oil ratio in the blend). The MUFA:PUFA ratio in the samples ranged from 1.4:1 to 1.6:1 with the recommended value being 1.5:1 (used to calculate the oil ratio in the blend). Therefore, the oil blends developed provide the recommended ALA:LA and MUFA:PUFA ratios.

### 3.5 Conclusions

The importance of oil blending lies in the ability to balance the fatty acid composition of vegetable oils. Research has led to the development of oil blends with a well-balanced ratio of monounsaturated and polyunsaturated fatty acids, as well as a harmonious balance of omega-3 and omega-6 fatty acids. Each oil blend contains three vegetable oils such as refined olive oil, rapeseed and sunflower oil, as well as unrefined corn oil and linseed oil, carefully selected based on their fatty acid profiles. The acid value (0.30–0.56 mg KOH/g), peroxide value (2.3–2.9 mmol O<sub>2</sub>/kg), and iodine value (112–145 g I<sub>2</sub>/100 g) of the developed oil blends were tested, with all values falling within the recommended ranges.

In the oil blends, saturated fatty acids ranged from 13.82% to 15.96%, with palmitic acid and stearic acid being the most abundant. The monounsaturated fatty acid content of the developed oil blends ranged from 49.57% to 52.5%, while the oleic acid content varied from 47.01% to 51.98%. The alpha-linolenic acid content ranged from 2.69% to 3.18%, while the linoleic acid content was 30.70–31.57%.

The developed blends of vegetable oils are recommended for use in culinary practice due to their optimal nutritional profiles. Specifically, the blends of flaxseed oil (4.01%) – olive oil (60.62%) – sunflower oil (35.37%), and corn oil (43.78%) – flaxseed oil (3.83%) – olive oil (52.39%) demonstrate the most favorable ratios of alpha-linolenic acid to linoleic acid, as well as monounsaturated to polyunsaturated fatty acids. These proportions align well with current dietary recommendations, making the blends ideal for promoting balanced nutrition in everyday cooking.

Further research should focus on the development of oil blends for a wider range of culinary applications. For example, flavored oil blends could be tested where herbs and spices are incorporated to enhance the aromatic properties. In addition, the vegetable oil blends developed can be further tailored for specific applications such as salad dressings, sauces, mayonnaise and even for cooking different foods, including frying and baking. This approach will help provide both consumers and the food industry with a variety of healthy and tasty foods.

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