



Physicochemical Changes in Blends of Vegetable Oils with Palm Olein During Deep Frying.

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Abstract

Daily nutrition relies on vegetable oils, as they provide essential fats and significantly contribute to overall good health. Sunflower, soybean, and palm olein oil are among the top oils, as they are valued for what they bring to food and nutrition. **Methods** The primary objective of this research was to examine the effects of blending sunflower oil and soybean oil with palm olein oil, followed by a comprehensive characterization of these oil mixtures based on critical parameters such as low melting points, peroxide numbers, and elevated oxidative stability. The study also investigated the physicochemical properties of these oil blends during the deep-frying process, which included an assessment of free fatty acid percentages, iodine values, peroxide values, and detailed fatty acid composition, ultimately identifying the optimal oil blends in terms of their physicochemical properties among palm olein, sunflower, and soybean oils during the deep-frying operation. **Results** Upon conducting the blending process of palm olein oil with both sunflower oil and soybean oil, the resultant mixtures exhibited favorable outcomes concerning free fatty acid content, peroxide number, and iodine value, which collectively contributed to a marked enhancement in the oxidative stability of both sunflower and soybean oils. The most effective blends were 50% palm olein oil with 50% soybean oil and 50% palm olein oil with 50% sunflower oil, both showing superior characteristics. **Conclusion** Throughout this investigation, we formulated and evaluated a multitude of diverse ratios of blended oils to one another. After deep frying for 1, 3, 6, and 8 hours, palm olein oil was found to be the most effective emerged as the most effective oil when compared to its counterparts, sunflower oil and soybean oil, particularly in the context of the oxidation process. This research not only provides invaluable insights into the potential for enhancing the quality of oils used in deep frying through strategic blending but also contributes positively to the advancement of public health and the overall improvement of food products available to consumers.

Keywords: Vegetable oils, palm olein, soybean oil, sunflower oil, physicochemical properties, deep frying, oxidative stability.

1. Introduction

It's normal to use high-heat oil for frying in both restaurants and food processing plants. The problem is that higher temperatures and spent time cause thermal degradation of oils. One big worry regarding cooking oils is whether they keep their stability. This instability arises from auto- and photo-oxidative processes that transpire during both processing and storage [1]. Lipid oxidation adversely affects the functional properties of raw materials, the sensory and nutritional quality of food products, and precipitates economic detriment [2]. The main outcome of lipid oxidation is rancidity which can make food taste unpleasant and leads to changes in how people perceive and score the food [3, 4]. The global community has become increasingly aware that a high concentration of saturated fats in dietary products constitutes a significant risk factor for coronary heart diseases, including atherosclerosis.

Increased consumption of unsaturated and polyunsaturated fats reduces the risk of coronary heart diseases [5, 6]. Notably, only omega-3 fatty acids have been demonstrated to play a crucial role in the prevention of cardiovascular diseases, whereas omega-6 fatty acids do not exhibit similar benefits [7-9]. Even so, these

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unsaturated fatty acids can easily become oxidized [10]. The oxidation of unsaturated fatty acids may arise through three distinct reaction pathways, contingent upon the environmental conditions and initiating factors involved. The undesirable alterations in oils during frying are, in part, influenced by the degree of unsaturation of the fatty acids present. Consequently, it is imperative to select an appropriate frying oil to inhibit its degradation. Characteristics such as high oxidative stability, elevated smoke point, minimal foaming, low melting point, and a neutral flavor profile are essential attributes of exemplary frying oils [11]. Mixing certain oils together is an efficient way to enhance their melting point, resistance to oxidation and iodine and peroxide values. The chemical characteristics of the oils, such as chain length and saturation/unsaturation, are related to their viscosity. It rises with increasing saturation and polymerization, while it falls with increasing unsaturation, as shown in [12].

Adding 20% palm olein to other vegetable oils improved transparency during shelf storage. The possibility of cloudiness and incomplete crystallization in palm olein can also be lessened by oil blending [13]. Palm oil, second only to soybean oil in global production, is the most popular frying oil [14]. Because of its high degree of saturation and mono-unsaturation, it possesses excellent oxidative stability. Compared to other vegetable oils, the presence of vitamin E (tocopherol) in palm oil enhances oxidative stability against rancidity [15]. Palm oil is now the second most widely used oil in the world, and it has a competitive price when compared to other oils that may be eaten. However, its high melting point limits its popularity despite its long shelf life, high oxidative stability, and rich content of vitamins and natural antioxidants [16]. Therefore, mixing these oils with saturated oils such as coconut oil (CCO), palm oil (PO), palm olein oil (POO), and palm kernel oil (PKO) is a smart way to balance the FA profile. Although saturated oils are more stable and less susceptible to oxidation than unsaturated oils, increased consumption of these oils has been linked to CVDs and a host of other health problems. Therefore, it is necessary to promote the intake of oils with a high UFAs content and a medium SFAs level that are able to withstand the rigors of frying. Traditional oils can be mixed to accomplish this [17].

This study aims to identify several mixtures of soybean oil and sunflower oil with palm olein that are distinguished by a low melting point, peroxide, and high oxidative stability. In addition, compare some physicochemical characteristics of these mixtures (refractive index, cloud points, melting point, smoke point, free fatty acid percentages, iodine values, peroxide values, fatty acid compositions, and oxidative stability) to those of other samples taken.

2. Materials and methods

2.1 Chemicals and reagents

All analytical-grade chemicals used in this study were provided by Oil Tec Company for Oil and Detergents, Sadat City, Menoufia, in 2024. Professional Lab also purchased these chemicals. The Oil Tc Company for Oil and Detergents in Sadat City, Menoufia, also provided the refined, bleached, and deodorized RBD sunflower oil (SFO), RBD soybean oil (SBO), and RBD palm olein oil (PO) in 2024.

2.2. Assessment of physicochemical and oxidative stability

2.2.1. Fatty acid composition (FAC) determination

Fatty acid composition (FAC) was determined using gas chromatography with a helium carrier gas flow rate of 6.8 mL/min. By analyzing the RM5 standard mixture of FAME (SupelcoCat. No: 47024, Tokyo, Japan), the correction reaction factors were identified. It took 60 minutes to complete the analysis. Comparing the retention periods of the FAME peaks to those of highly purified FAME standards allowed for their identification. A little more than 1.0 g of the oil sample was weighed and transferred to a 50 mL round-bottom flask. Using a funnel, 5.0 mL of potassium hydroxide in methanol (KOH MeOH solution (0.1 M)) and boiling chips were transferred (AOCS Ce 2-66 reapproved 2017) [50].

The flask was placed in a reflux condenser and boiled for five minutes. After five minutes of boiling, 5 mL of boron trifluoride (BF₃) in methanol solution (14% BF₃ and 86% methanol) was added, and the mixture was boiled for another three minutes. The methylation sample was cooled down, 10 mL of isooctane was added, and around 5 mL of saturated sodium chloride was added, followed by vigorous mixing for 10 seconds. After phase separation, 1.5 mL was taken and put into a vial before being injected into the gas chromatograph.

2.2.2. Color measurement

Color was measured using the Lovibond Tintometer according to AOCS method Cc 13b-45 [19, 20].

2.2.3. Peroxide value (PV) determination

We employed the method of (AOCS Cd 8-53 by Acetic Acid-Chloroform Method) [49]. The oil sample (2.5 g) was first dissolved in a mixture of glacial acid and chloroform (30 mL, 3:2 v/v), and then prepared potassium iodide (KI) solution (1 mL) was added. Finally, the oil sample was titrated slowly with a sodium thiosulphate (Na₂S₂O₃) solution (0.1 N) in the presence of a starch solution (1%) as an indicator. Peroxide value (PV) was expressed as meq O₂/kg oil, with each sample tested in duplicate. Hydroperoxides decompose into aldehydes and ketones, among other components, and the starting PV for oils used for frying should ideally be less than 1 meqO₂/kg, regardless of the oil composition. The formula used to determine PV is as follows:

$$PV (meq/O_2 \text{ kg sample}) = S \times N \times 1000/G$$

Here, G represents the weight of the oil sample in grams, N represents the normality of the sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) solution in mL, and S represents the mL of sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) (blank corrected).

2.2.4. Determination of the iodine value (IV)

We determined the IV using the (AOCS Cd 1c-85 reapproved 2009) [52] technique Cd 1c85. Frying oils are deemed to be ruined if the IV of palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2), and alpha linolenic acid (C18:3) falls in comparison to the IV of virgin oil [21]. The fatty acid methyl esters of oils were measured to create a novel IV calculation method. The suggested calculation equation was

$$IV = xC1 + yC2 + zC3$$

where the sum of the methyl esters of monounsaturated, di-unsaturated, and tri-unsaturated fatty acids is equal to C1, C2, and C3. The Wijs method produces findings that are more consistent with the recommended calculation than with the corresponding AOCS technique.

2.2.5. Free Fatty Acid (FFA) Determination

(The AOCS Ca 5a-40) [51] procedure Ca 5a40 was used to determine the FFA. The proportion of oleic acid was calculated as the FFA using the formula below:

$$\text{Vol. of } 0.1N \text{ NaOH} \times N \text{ NaOH} \times M / \text{Weight of sample (g)} = \text{Free Fatty Acid \%}$$

Where: The amount of alkali utilized in the titration Vol. of 0.1 N NaOH = M = 28.2 for oleic acid N = 0.1 N NaOH.

2.2.6. Acid Value Determination

The following formula, which employs the free fatty acid (FFA) proportion derived from the titration method, was used to calculate the acid value: $\text{Acid Value (mg KOH/g)} = (\text{FFA\%} \times 1.99)$

where: The free fatty acid percentage, or FFA%, is calculated using titration. The conversion factor, 1.99, takes into account the molecular weight of oleic acid, the reference fatty acid utilized in this study, and the equivalent weight of potassium hydroxide (KOH).

2.2.7. Oxidative Stability Index (OSI) Determination

The oxidative stability index (OSI) was measured using method number AOCS Cd 12 57. A sample of 2.5 g $\pm$ 0.01 g was used to ascertain the oxidative stability using 743 Racemate machines from Metrohm, Hersau, Switzerland. All the samples were examined at the same temperature of 110 °C with a continuous air flow (20 l/h). With an accuracy of 0.005, the program automatically printed the induction times. This approach represents the amount of time it takes for oil to withstand oxidation at high temperatures [22].

3. Results and Discussion

3.1. Peroxide Value (P. V.)

Data summarized in Fig. 1 show that peroxide value (PV) of blended oils increased with frying time. The highest PV, was for 100SB (13.4 meq O_2/kg), followed by 100SF (11.5 meq O_2/kg), after frying. The peroxide values for 100SB and 100SF were higher than the permitted limit of 10 meq O_2/kg , but the lowest values were for the blends of 50SF with 50PO (5.5 meq O_2/kg). The peroxide number rose noticeably with longer heating periods [23]. These data showed that the peroxide values of all mixed oils increased as a result of increasing heating time. At the start of heating, the peroxide numbers rose [24].

The rise in this study lasted for the first eight hours. The outcome is nearly the same as when a combination of palm, soybean, and sunflower oils is used. The deterioration of peroxides, which were created during the primary and secondary oxidation processes [25], may be the cause of these increases. A reduction in peroxide value was occasionally observed with increased heating duration. This is because, during heating, the created peroxides are not stable at high temperatures and frying periods, and they break down into aldehydes and carbonyls [26].

Many reports indicate that temperature plays a major role in breaking down lipids. The effect is significant above 200°C. As a result, the ideal temperature for heat is 180°C. A high quality cooking oil should have a peroxide value of no more than 10 meq O_2/kg , as peroxide values over 10 meq O_2/kg indicate spoilage [27]. According to lab trials and findings, in some blended oils, heating for 0 to 8 hours still satisfied the criteria. The blend with the lowest peroxide value was 50SF:50PO. The data revealed that the inclusion of palm olein in the mixture enhanced its oxidative stability. We discovered that mixing palm oil, which has a high oleic acid concentration and high antioxidant levels, with sunflower oil helps to increase its oxidative stability [28].

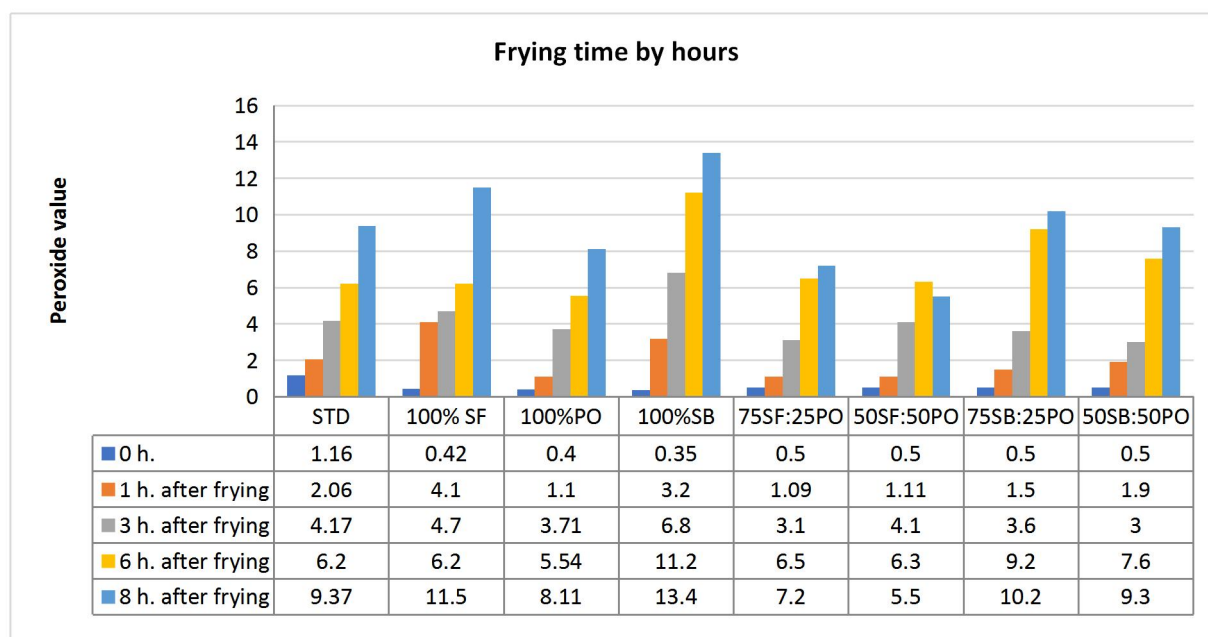


Fig. 1. Peroxide value of oils during different frying times

3.2. Free fatty acid (FFA)

As a consequence of triacylglycerol hydrolysis during frying, free fatty acids are released. These fatty acids tend to undergo thermal oxidation, producing off flavors and scents in the frying environment and fried foods [29]. The difference in the proportion of free fatty acids (FFA) in different oils and their blends is shown by the data obtained in Fig. 2. In all frying oils, the FFA level progressively rose as the frying duration increased, according to these findings. On the other hand, the least amount of FFA was found in mixes 50SB:50PO (0.21%) and 50SF:50PO (0.24%), respectively, while the most FFA was found in 100SF (0.39).

We discovered that blends with a lower percentage of palm olein oil and a greater percentage of sunflower and soybean oil had the highest FFA. This suggests that mixing oils with palm olein oil enhances their oxidative stability during frying. This might be because palm olein has a high concentration of antioxidants like carotenoids and tocopherols by nature [30, 32]. The quantity of FFA in oil is influenced and determined by a variety of variables, including the amount of water, the food releases into the frying medium, the food's makeup, the frying temperature, the oil turnover time, and the build-up of scorched food particles [33, 34].

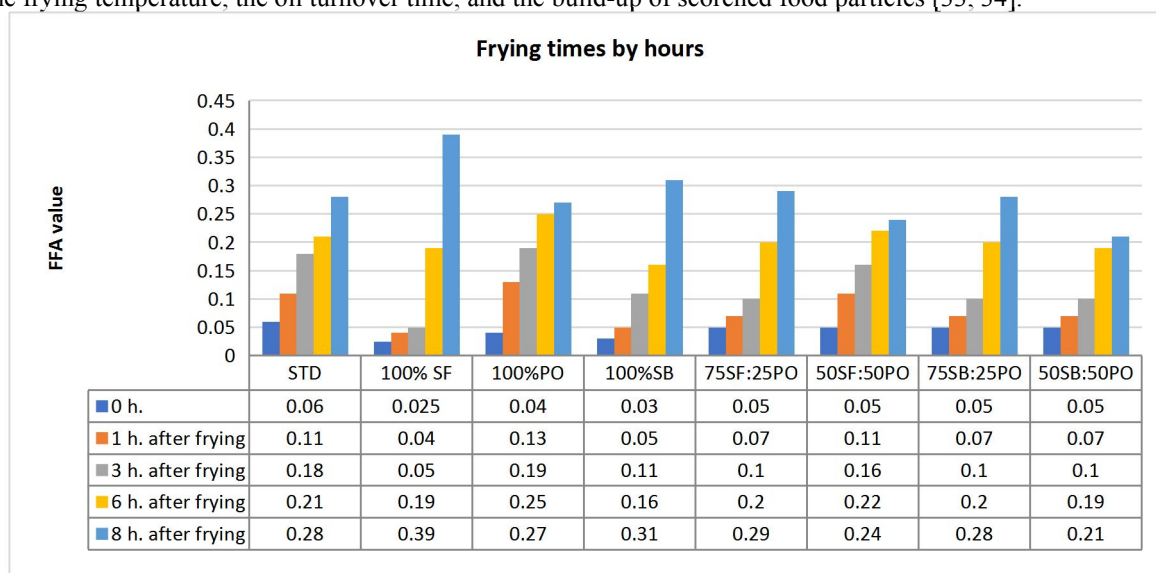


Fig. 2. Free fatty acid of oils during different frying times

3.3. Iodine value (IV)

The Iodine value (IV), which is frequently used to determine the genuineness of fats and oils, is a measure of the degree of unsaturation. Palm olein oil was the only exception; the IV of all the oils was originally quite high when they were RBD. The IVs for the various oil mixes are quite different. It was predicted, nevertheless, that the IV would fall with exposure to light and air and would follow the proportion of the mixture of two oils due to the decline in unsaturation. The high temperature and length of heating in heating oil led to oxidation, hydrolysis, and breakdown of oils [35]. The decreasing amount of double bonds that are oxidized during the frying procedure [36, 37] is consistent with the drop in IV.

A greater thermos oxidative change results in a decrease in the iodine value of the oil, suggesting an increase in the degree of oxidation. The high saturation level of palm olein oil makes it unsuitable for sole use in frying since it may be related to polymerization and oxidation processes involving double bonds [24]. Due to its potential threat to consumer health, the IV reduction is a cause of risk to the consumer's health, and this explains why frying with palm olein oil alone has a negative effect on health due to its high saturation level. The iodine value (IV) of all the oils utilized in this study decreased dramatically after being fried for eight hours, as shown in Fig. 3. Compared to STD, the 100SF (control) experienced the greatest loss of unsaturation; the iodine value for 100SF (control) was 128.7 g I₂/100 before frying and dropped to 114.8 g I₂/100 at the conclusion of frying (8 h).

This drop in IV is indicative of the degree of oxidation-induced decrease in the oil's degree of unsaturation [38]. Additionally, we observed that 100POO had the lowest IV reduction (56.12 g I₂/100) at the end of the 8-hour frying period. This could be explained by the high proportion of saturated bonds found in palm olein oil. Heating or frying caused this number to decrease as unsaturated bonds were broken to become saturated. The IV of the combination of 50SF50PO was roughly 88.9 g I₂/100 after 8 hours of frying, which was about the same as the IV of the combination of 50SB50PO (86.8 g I₂/100). Therefore, this suggests that after 8 hours of frying, these mixtures experienced less oxidative rancidity. The high concentration of saturated fatty acids in palm olein, such as oleic acid, reduced oxidation.

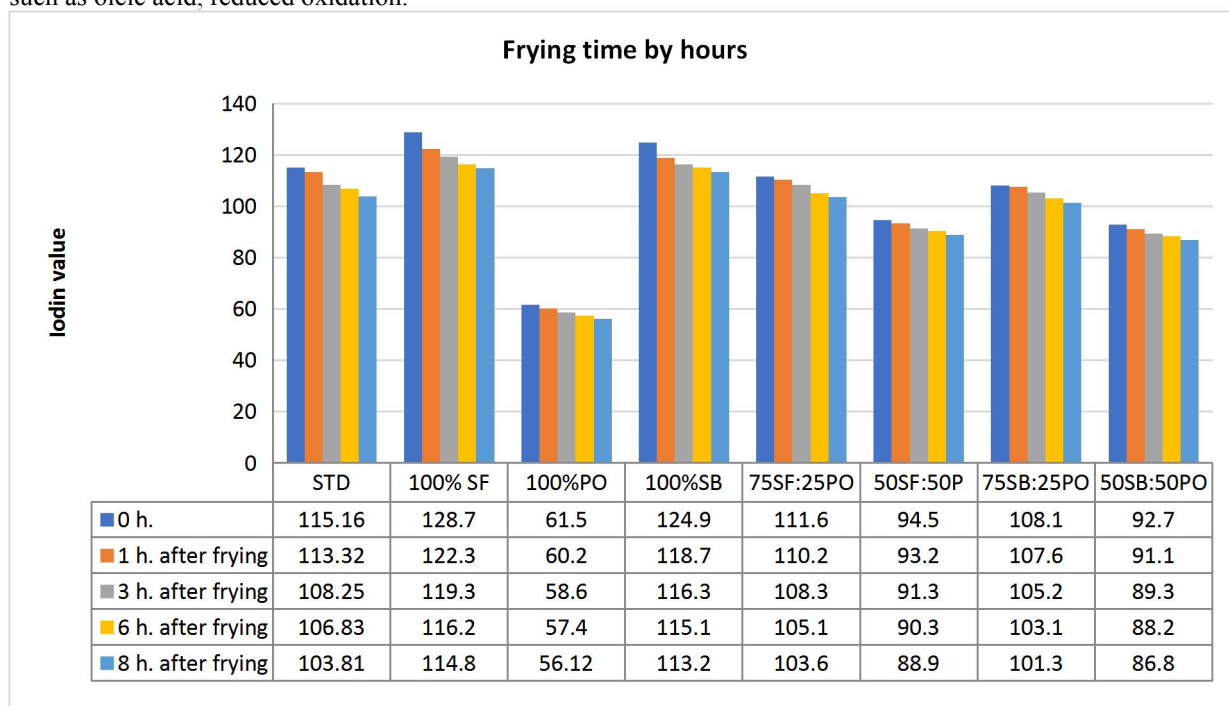


Fig. 3. The values of Iodine number during different times of frying

3.4. The color (red/yellow/blue)

One of the physical indicators used to determine the quality of frying oil is its color. The darkening of oil while frying is an undesirable property in many countries, the oil's color serves as a clear indicator that it should be thrown away [39]. The oil color index is determined by the sum of all the breakdown products that contribute to oil darkening [21,40]. The alterations in the oils' color during frying are illustrated in Fig. 4 and 5 (Red/yellow/blue Unit). The oil combination's color varied throughout the course of eight hours of frying. In every oil combination, the increase in color was noticeable. The greatest rise in color was seen in SF100% (10.9/33/4.5), 50SB50PO (11.5/33/7.5), and SB100% (13/33/7.5), respectively. Conversely, we saw the least amount of color reduction in 50SF50PO (7.2/31/4.5), 75SF25PO (7.5/31/5.3), and 75SB25PO (9.2/33/4.2).

The polymerization of unsaturated carbonyl compounds and nonpolar compounds of food stuff solubilized in the oil is the cause of the oil's darkening during deep fat frying [41]. From three to eight hours, the color with a higher ratio of palm olein increased noticeably. This can be explained by the diffusion of browning pigments produced by fried food and color reversion [20, 42]. Palm oil's color changes more quickly than other oils during frying. It was noted that the 50SF50PO combination had the best color quality at the conclusion of frying at (7. 2/31/4. 5). Compared to other blended oils, the color did not significantly increase between 3 and 8 hours. Palm olein oil containing mixtures thus showed greater resistance to color degradation when fried. Changes in color alone were not enough to monitor, since additional factors, such as the iodine value, total polar compound, and oxidation stability of frying oils, must also be taken into account [40, 43–44].

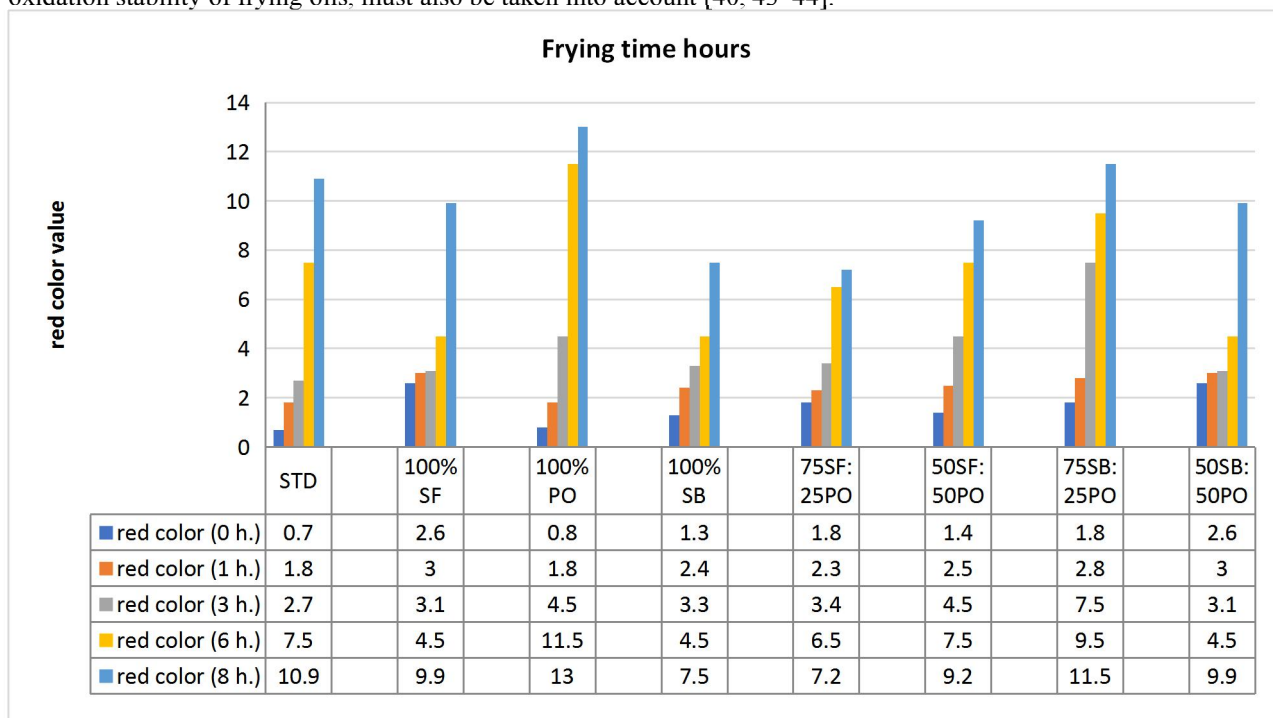


Fig. 4. Red color changes of oils during different frying times

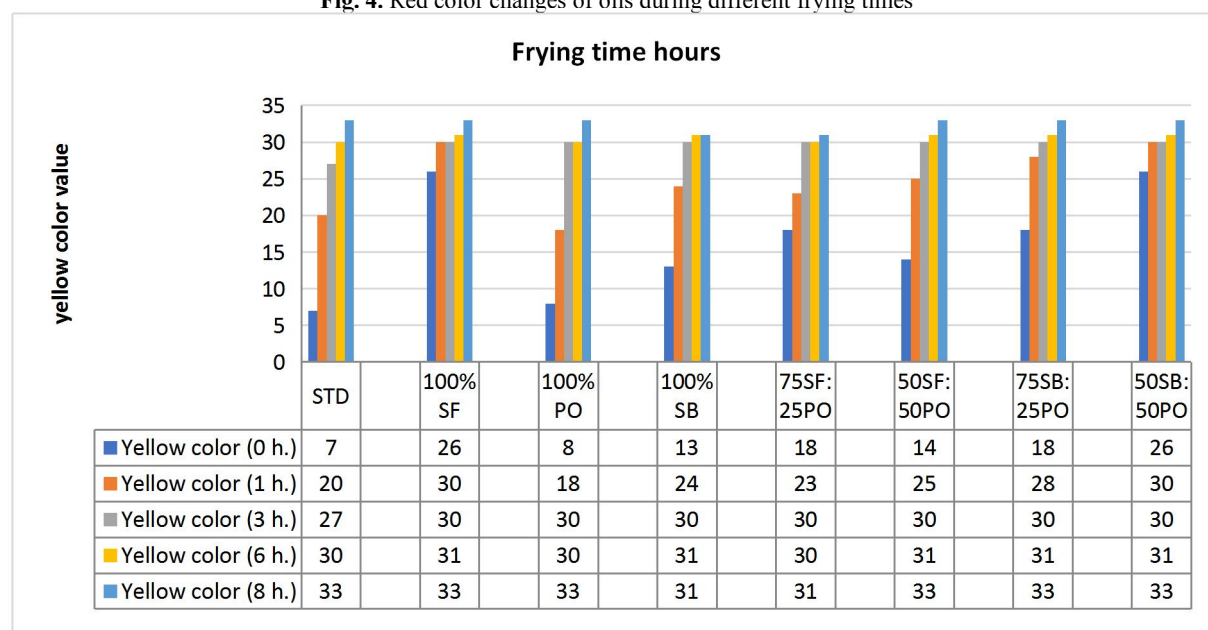


Fig. 5. Yellow color changes of oils during different frying times

3.5. Gas Chromatography for Fatty Acid Composition

The proportion of unsaturated fatty acids decreased due to the heating process. Due to variations in fatty acid composition, the kind of oil used in the heating treatment influences the change in stability [33]. From

Table 1, we can see a notable drop in linolenic, polyunsaturated, and monounsaturated acids in contrast to the relative rise in palmitic, stearic, and arachidic oleic acids. Polyunsaturated fatty acids are more easily oxidized than saturated fatty acids. As a general rule, the proportion of linoleic acid reduces with heating time. In this experiment, all oil and blends exhibited a decrease over the course of eight hours. The linoleic acid (C18:2) reduction theory, which was converted during the frying process to the main and secondary oxidation products of unsaturated fatty acid oxidation. The linoleic acid ratio is frequently employed as a measure to assess the extent of fat and oil deterioration [32].

This is because linoleic acid is more prone to oxidation. In 100RPO, the smallest reduction in linolenic and linoleic acid was seen. Monounsaturated Fatty Acids (MUFA) and Saturated Fatty Acids (SFA) are more stable than unsaturated and polyunsaturated fatty acids (PUFA). Monounsaturated fatty acid levels were impacted by heating-related variables, while increasing temperature causes an increase in SFA content [45]. Palm olein oil has a total unsaturated fatty acid content of 49.73%, with 39% oleic acid and 10.73% linoleic acid, respectively. In contrast, 39.3% of saturated fatty acids are palmitic acids. This indicates that mixing palm olein with other vegetable oils lowers the concentration of linoleic acid and linolenic acid to a level comparable to partial hydrogenation without producing any identifiable trans free fatty acid isomers [30]. The mixing oil could increase the stability of single oils throughout the frying process. Fats and oils with higher saturated fatty acid content exhibit greater resistance to oxidative modification [46, 47]. The physicochemical, nutritional, and sensory qualities of the oil are altered during deep frying.

This is the outcome of a variety of complicated processes that take place during the process, including hydrolysis, isomerization, cyclization, oxidation, and polymerization, which change the flavor and break down the oil chemicals [48]. Because all physicochemical parameters are altered, and the flavor and aroma are unpleasant, the finishing oils are not desirable. Additionally, the buildup of harmful compounds in cooking oils and foods has a 263+ health. The oil may deteriorate to the point where it is no longer safe to use and should be discarded after several frying.

Table 1. The impact of mixing palm olein oil with sunflower and soybean oil on the fatty acid makeup of the oils during frying

	C16:0 (Palmitic acid)		C18:0 (Stearic acid)		C18:1 (Oleic acid)		C18:2 (Linoleic acid)		C18:3 (Linolenic acid)	
	Before frying	After frying	Before frying	After frying	Before frying	After frying	Before frying	After frying	Before frying	After frying
100% SF	7.169	8.253	3.713	4.161	28.776	29.100	59.944	58.273	0.214	0.186
100%PO	39.300	40.409	3.500	4.203	39.000	42.331	10.732	10.576	0.250	0.241
100%SB	12.209	13.775	5.420	6.048	25.034	31.817	51.633	46.768	0.209	0.180
75SF25PO	20.623	21.836	2.813	3.819	32.764	33.088	47.644	45.973	0.223	0.195
50SF50PO	25.323	27.504	4.280	3.839	37.173	37.516	33.108	30.711	0.042	ND
75SB25O	22.835	23.474	3.260	4.123	30.705	31.670	40.335	39.062	2.227	2.204
50SB50PO	27.714	27.716	4.807	4.693	30.818	31.821	29.672	29.591	2.051	1.936

100SF: 100% sunflower oil, 100SB: 100% soybean oil, 100POO: 100% palm olein oil, 75SF25POO: 75% sunflower oil and 25% palm olein oil, 50SF50POO: 50% sunflower oil and 50% palm olein oil, 75SB25POO: 75% soybean oil and 25% palm olein oil, 50SB50POO: 50% soybean oil and 50% palm olein oil.

4. Conclusions

Rapid oxidation of single vegetable oils such as soybean and sunflower oils, was observed due to the high level of unsaturated fatty acids they contain, resulting in a rise in peroxide and free fatty acid values during deep frying.

Oxidation, rancidity and decomposition were shown to be reduced when fresh chip paste potatoes were fried only in palm olein oil. This is due to its content of many saturated bonds in addition to containing natural antioxidants such as tocopherol. However, from a health perspective, when used frequently, it may lead to heart disease and other diseases in the long run. As a result, there was consideration of mixing palm olein oil with other vegetable oils, like soybean and sunflower oil.

Mixing palm olein oil with soybean or sunflower oil in different portions makes the oil better for health and use. As a result, mixing is thought to be the best option for deep frying due to its physicochemical characteristics. The frying performance and oxidative stability are greatly enhanced by combining soybean oil or sunflower oil with 25% palm olein.

The two best mixtures in terms of physicochemical properties (peroxide number, free fatty acid, color, iodine number, and GC analysis) were determined to be 50% palm olein oil with 50% soybean oil and 50% palm olein oil with 50% sunflower oil after studying the results of earlier practical studies.

This study supports oil manufacturers in producing blends of these oils for deep frying in restaurants and homes, complementing other oils used for cooking. This mixture will be economically suitable for the consumer and have nutritional value at the same time.

Suggestions for deep frying, according to the study, using palm olein oil together with equal amounts of soybean or sunflower oil is best for using in a fryer. The results enable manufacturers to create better frying oils that satisfy market demands and provide consumers with healthier alternatives. More research should be conducted to examine how these combinations change the nutritional values of fried foods.

Significance of this research work: This research highlights the importance of oil blending to improve quality and suitability for deep frying. Also, offer healthier and more economical alternatives to commonly used deep-frying oils as well as help manufacturers in producing enhanced oil blends that meet consumer needs.

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Ethics statements We hereby confirm that the Ethical Review Committee at the Faculty of Specific Education in Egypt gave its approval and informed consent to the research protocol entitled "Physicochemical Changes of Blends in some Vegetable Oils with Palm Olein Oil during Deep Frying" with code (ZU / FSE / 2025/03/No. 1).

5. Conflicts of interest

"There are no conflicts to declare".

6. Formatting of funding sources

We have no funds from any agency or institute.

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