

A REVIEW: BLENDING VEGETABLE OILS FOR ENHANCED OXIDATIVE STABILITY AND NUTRITIONAL BENEFITS

Tran Thi Ly^{1*}, Pham Thi Vinh², Yang Ligang¹, Sun Guiju¹

School of Public Health - Southeast University, China, TNU - University of Agriculture and Forestry

ARTICLE INFO	ABSTRACT
Received: 05/01/2024 Revised: 03/12/2024 Published: 03/12/2024 KEYWORDS Vegetable oil blends Oxidative stability Sensory properties Chemical properties Nutritional properties	Blending vegetable oils with different properties is one of the simplest methods to create new oil blends with desirable structural and oxidation properties. Different oils have distinct physical and chemical properties, and the use of a single vegetable oil may limit its properties, such as physical properties, chemical properties, nutrition, and oxidative stability. Therefore, blending different vegetable oils is a simple method to exploit the unique properties of each oil. Oil blending is a topic of current interest, captivating the attention of numerous researchers. This study aims to examine a compilation of related research on vegetable oil blending, thereby providing a comprehensive assessment of the impact of oil blending on the advantages of blended oils, such as: (1) Blending oils to enhance the physical and sensory properties of oil blending; (2) Oil blending is employed to augment the physical and sensory characteristics of oil blending; (3) blending oils for enhancing nutritional properties of oil blending. The blending of vegetable oils has become a widely accepted standard in many countries and is anticipated to continue as a prevailing trend in the modern industry, meeting the increasing nutritional and health demands of consumers.

ĐÁNH GIÁ: PHA TRỘN DẦU THỰC VẬT NHẪM TĂNG CAO ĐỘ ỔN ĐỊNH OXY HÓA VÀ LỢI ÍCH VỀ DINH DƯỠNG

Trần Thị Lý^{1*}, Phạm Thị Vinh², Yang Ligang¹, Sun Guiju¹

¹Viện Y tế Công cộng - Đại học Đông Nam, Trung Quốc, ²Trường Đại học Nông Lâm – ĐH Thái Nguyên

THÔNG TIN BÀI BÁO	TÓM TẮT
Ngày nhận bài: 05/01/2024 Ngày hoàn thiện: 03/12/2024 Ngày đăng: 03/12/2024 TỪ KHÓA Dầu thực vật pha trộn Độ ổn định oxy hóa Tính chất cảm quan Tính chất hóa học Tính chất dinh dưỡng	Việc pha trộn các loại dầu thực vật với các đặc tính khác nhau là một trong những phương pháp đơn giản nhất để tạo ra hỗn hợp dầu mới với các đặc tính cấu trúc và oxy hóa mong muốn. Các loại dầu khác nhau có tính chất vật lý và tính chất hóa học riêng biệt, và việc sử dụng riêng lẻ một loại dầu thực vật có thể hạn chế các đặc tính của nó, chẳng hạn như tính chất vật lý, tính chất hóa học, dinh dưỡng và độ ổn định oxy hóa. Vì vậy, pha trộn các loại dầu thực vật khác nhau là phương pháp đơn giản để khai thác những đặc tính riêng của từng loại dầu. Việc pha trộn dầu đang là một chủ đề đang thu hút sự chú ý của nhiều nhà nghiên cứu. Nghiên cứu này nhằm mục đích đánh giá một cách tổng hợp các nghiên cứu liên quan về việc pha trộn dầu thực vật, từ đó cung cấp một đánh giá tổng thể về ảnh hưởng việc pha trộn các loại dầu lên lợi ích mang lại của dầu hỗn hợp, chẳng hạn như: (1) Pha trộn dầu để tăng cường các đặc tính vật lý và giác quan của dầu pha trộn; (2) Pha trộn dầu được áp dụng để làm tăng cường các đặc tính vật lý và cảm quan của dầu pha trộn; (3) Pha trộn dầu để tăng cường các đặc tính dinh dưỡng của dầu pha trộn. Việc pha trộn các loại dầu thực vật đã trở thành một tiêu chuẩn được chấp nhận rộng rãi ở nhiều quốc gia và được dự đoán sẽ tiếp tục là xu hướng thịnh hành trong ngành công nghiệp hiện đại, đáp ứng nhu cầu dinh dưỡng và sức khỏe ngày càng cao của người tiêu dùng.

DOI: <https://doi.org/10.34238/tnu-jst.9543>

* Corresponding author. Email: lytran@thaibinhseed.vn

1. Introduction

Dietary fats contribute desirable physical, nutritional, and sensory properties to food [1]. Vegetable oils, serving as the primary source of fat in our diets, are frequently used as cooking mediums in various culinary preparations. In recent times, there has been a growing recognition of the nutritional quality of fats and oils, especially regarding their association with circulatory and nervous system-related diseases. In 2015, cardiovascular diseases were responsible for 17.7 million global deaths, and this number is projected to rise to 23.3 million in the future [2]. Consequently, there has been an increased focus on the consumption of fats and oils due to the rapid increase in cardiovascular diseases. The inherent chemical and physical properties of many vegetable oils often restrict their direct application in the food industry. To enhance their practical utility, vegetable oils undergo modification through four distinct techniques: hydrogenation, interesterification, fractionation, and blending, as discussed by many authors [3], [4].

Hydrogenation is a well-established method employed to enhance the texture and oxidative stability of vegetable oils. This process involves the use of hydrogen gas and nickel as a catalyst to saturate certain double bonds within unsaturated fatty acids. However, it is important to note that hydrogenation can result in the isomerization of some double bonds, transforming them from a cis state to a trans state. Trans fatty acids are widely recognized for their adverse health effects and their potential to contribute to various diseases, as highlighted by Dijkstra and Duijn [5]. Alternatively, interesterification offers a method for modifying vegetable oils without the saturation or isomerization associated with hydrogenation. This process redistributes fatty acids within the triglyceride structure. Nonetheless, it requires specialized equipment and tends to be more costly, as explained by Santoro et al. [6]. Fractionation is a procedure that segregates certain fats and oils into two distinct fractions, each possessing different melting and textural properties. This approach is commonly employed with specific fats and oils such as palm oil or tallow. Fractionation can be undertaken as an independent process or as a preliminary treatment before hydrogenation, interesterification, or blending, as elucidated by Dijkstra and Duijn [5].

The blending of vegetable oils with different properties stands out as one of the simplest methods for creating distinct products with desired textural and oxidative characteristics. Various fats and oils exhibit distinct physical and chemical properties. Using a single type of vegetable oil may limit its inherent properties, such as oxidative stability and nutritional properties and. Hence, the practice of blending different vegetable oils provides a straightforward means of harnessing the diverse characteristic properties of each oil. Blending vegetable oils has been a well-established and widely accepted practice in numerous countries [3], [7]. Blending many different types of oil is a time-saving way to change of physicochemical characteristics and does not have any adverse health effect [8], [9].

Oil blending is a subject of significant concern and has attracted the attention of many researchers. As such, the aim of this study is to review a set of relevant research on oil blending, thereby facilitating a comprehensive evaluation of the influence of oil blending on the enhancement of oxidative stability, as well as nutritional characteristics benefits.

2. Methodology

A bibliographic search was carried out from 2012 to 2022. The following terms were particularly searched, always in combination with "Vegetable oil blend", "Edible oil blend", "Vegetable oil blend and Health effect", and "Oxidative stability of vegetable oil blend" on major search sources such as SCOPUS; WEB OF SCIENCE; NCBI.

3. Result and discussion

3.1. Blending oils for enhancing physical and sensory properties

Incorporating a range of oils, each characterized by unique properties yields a novel oil with enhanced functional attributes, ideal for diverse applications in the final product. For example,

certain oils exhibit crystallization and altered clarity upon cooling. Empirical investigations have demonstrated that the oil blend of 80:20 (canola: olive) with 20% palm olein produces a more stable and clearer blend, ensuring stability throughout the storage period [8].

Palm oil, characterized by its enhanced saturated fatty acid content and rapid crystallization attributes, demonstrates enhanced fluidity through blending with canola oil or flaxseed oil. The 70:30 blends of palm oil: canola oil improved the qualities of the crisps better than canola oil alone. The blending Flaxseed oil with Palm oil with ratio of 72 and 6 greatly enhanced its oxidation stability. These mixtures exhibit broader applicability within the realm of the food industry [10], [11]. Combining different oils results in alterations to the triacylglycerol composition. The combination of blending palm oil and canola oil with different ratios of B1 (90 : 10), B2 (80 : 20), B3 (70 : 30), B4 (60 : 40), B5 (50 : 50), B6 (40 : 60), B7 (30 : 70), B8 (20 : 80), and B9 (10 : 90) improved better its physicochemical properties during hydrolysis and oxidative processes. Consequently, this leads to modifications in the inherent characteristics of oils, including solid fat content, cloud points, density, smoke points, viscosity, and sensory properties [3].

The smoke point is defined as the temperature at which fats/oils generate continuous smoke when subjected to heating. In their study conducted in 2013, Choudhary et al. [12] examined the impact of deep frying on combinations of various oils (including olive, soybean, groundnut, mustard, sunflower, and palm olein oils) with rice bran oil. Their findings revealed that both ratios of 70:30 and 80:20 in the combination of rice bran oil and non-conventional oil exhibited enhanced nutritional characteristics and an elevated smoke point [12].

Viscosity plays a critical role, particularly in deep frying. The successive deep-frying in 30 hours was applied for the essential oil of the fruits of *Amomum villosum* Lour. This process results in the formation of primary and secondary oxidation byproducts, which, in turn, lead to an increase in the viscosity of the cooking oils [13]. Opting to blend oils with high stability and favorable nutritional attributes represents a judicious approach to reducing viscosity and mitigating oxidation.

Combining oils with divergent characteristics can yield an oil blend possessing exceptional stability at frying temperatures without necessitating hydrogenation or the generation of trans fatty acids. For example, the blends of Refined rice bran oil with Mustard oil and Palm Olein oil, renowned for its elevated content of oryzanol and sitosterol, potent antioxidants, can effectively curtail oxidation rates and, in some cases, forestall the oxidation process in the resultant blend, consequently diminishing viscosity increments during the deep-frying process at $180 \pm 1^\circ\text{C}$ for 24 hours [14] - [16].

Color plays a crucial role in influencing consumer preferences. Pure oils possess distinct colors, with some being highly pigmented while others have relatively faint tints, potentially impacting their appeal to consumers. By skillfully blending oils, it is possible to mitigate or enhance their color characteristics as needed. Additionally, the accumulation of oxidative compounds can intensify the coloration and darken the oils over time. Research findings indicate that the soybean oil and camellia oil with blend (60:40) and blend (50:50) can effectively retard the darkening process during deep frying, as demonstrated in studies by Wang et al. [17].

Blending different oils has the potential to bring about alterations in odor profiles, and significantly influences the organoleptic acceptability of the product. Empirical assessments of various oil blends have revealed that mixing oils can moderate the distinctive characteristics of each oil, ultimately yielding a more suitable product [18]. Process of blending oils assumes a pivotal role in shaping the sensory characteristics of the final product. The sensory qualities of food products are profoundly impacted by chemical reactions that transpire within oils and fats during the frying process, encompassing oxidation, thermal decomposition, hydrolysis, and isomerization or cyclization. These reactions tend to exert an increasingly adverse influence on oils as frying progresses [19]. The blend of coconut and groundnut oil blend showed the highest ratio (58.8%) of unsaturated to saturated fatty acids. In addition, polyunsaturated linoleic acid

(18:2; 24.3%), α -linoleic acid (18:2; 5%), oleic acid (18:1; 25%), capric acid (2.8%), lauric acid (1.8%), myristic acid (1.6%), palmitic acid (16:0; 14.5%), and steric acid (18:0; 9.2%) also were seen in this blend [19]. Therefore, a comprehensive understanding of oil properties and selecting the right ones for blending, we can mitigate these unfavorable reactions and enhance both their nutritional value and sensory appeal. Some recent researches on stable physical and sensory properties of oil blends and their suitable ratio have summarized in Table 1.

Table 1. Recent researches on stable physical and sensory properties of oil blends and their suitable ratio

Oil blend	References
Canola oil : Olive oil : Palm olein oil (64:16:20)	[8]
Palm oil : Canola oil (70:30)	[10], [11]
Palm oil : Canola oil (90:10, 30:70, 10:90)	[3]
Rice bran oil : Non-conventional oil (80:20 and 70:30)	[12]
Sunflower oil : Sesame oil (50:50)	[14]
Refined rice bran oil : Soybean oil : Mustard oil (60:20:20)	[15]
Soybean oil : Camellia oil (60:40 and 50:50)	[17]
Coconut oil : Groundnut oil (60:40)	[19]

3.2. Blending oils for enhancing chemical properties

Blending various vegetable oils can result in changes to the fatty acid composition, and increased presence of natural antioxidants and bioactive lipids within the mixture. As a consequence, this can potentially improve the nutritional value and longevity of the newly created blend oils. Furthermore, the resistance of the oil to oxidation is intrinsically connected to its shelf life. The blending of soybean oil (70%) with 17.7% lentisk oil and 12.3% sesame oil is acknowledged as a cost-effective method for altering their physicochemical properties, thereby enhancing their ability to withstand oxidative processes and fatty acids particularly essential fatty acids (linoleic acid and linolenic acid) [20]. Although the concept of oxidative stability has long been a subject of research interest, its significance is increasing as recent studies have unveiled its direct associations with oxidative deterioration. This oxidative process affects the chemical compositions of vegetable oils by saturating their fatty acids and generating reactive oxygen species (ROS). These ROS have the potential to cause detrimental effects on the normal function of endothelial cells and increase the risk of hypertension or the development of cancer [21], [22].

Furthermore, in some cases, oxidative stability is intertwined with other components. For example, the fusion of cold-pressed black cumin oil with sunflower oil may leave the primary fatty acid composition unchanged, yet the oxidative stability of the blend is enhanced due to an elevated content of thymoquinone and tocopherols within the mixed oils [23].

Additionally, other unconventional oils like Basil oil, cinnamon oil, black cumin oil, coriander oil, mustard oil, lemon verbena oils and Perilla seed oil have demonstrated beneficial and functional effects within the blending process [24] – [29].

Blending different vegetable oils can also exert an influence on both the predominant and subsidiary constituents present in the resulting blend. Certain subsidiary constituents, including β -tocopherols, carotene, oryzanol, and lignans which exist in varying quantities across different oils, impart advantageous effects on health and contribute to oil stability. For instance, when blending palm oil with rice bran oil, coconut oil at a ratio of 40:30:30 that each of which contains natural antioxidants such as α -tocopherol and γ -oryzanol. The outcome demonstrated that the nutritional content of the blended oils increased and the rate of oxidation occurs more slowly in these oil blends during frying processes [30].

Nonetheless, it is worth noting that oil blending can also be employed for adulteration purposes in certain instances, with the aim of increasing profitability. Such adulteration can be discerned through the analysis of specific markers found in the composition of vegetable oils. Virgin olive oil, in particular, is a target for adulteration due to its elevated market price.

Phytosterols, which represent minor components in vegetable oils, serve as a valuable means to identify adulteration in high-quality virgin olive oils [29], [8]. The blending oils for enhancing chemical properties has summarized in Table 2.

Table 2. *Effects of different oil blends on chemical properties*

Oil blend	Chemical properties	References
Soybean oil : Lentisk oil : Sesame oil (70:17.7:12.3)	Enhancing their ability to withstand oxidative processes and fatty acids particularly essentials fatty acids (linoleic acid and linolenic acid)	[20]
Cold-pressed black cumin oil : Sunflower oil (45:65)	Increasing oxidative stability of blends during storage due to the changes in the levels of thymoquinone	[23]
Basil essential oil (200 or 500 ppm) : palm olein	Lower p-anisidine values and free fatty acids contents	[24]
Lemon verbena essential oil (1,600 ppm) : sunflower oil	Increase the stability and stabilization effects in terms of storage conditions	[28]
Perilla seed oil : Extra virgin olive oil (45:65)	Increase oxidation stability, sensory acceptability	[29]
Rice bran oil : coconut oil : Palm oil (30:30:40)	The oxidative stabilities of the oil blends were better, there was no significant difference in sensory attributes	[30]
Oil blend of 80:20 (canola: olive) with 20% palm olein	Increasing iodine value, decreasing peroxide content, the lowest free fatty acid value	[8]
Rapeseed oil : Rice bran oil : Black cumin oil (10:30:60)	Enhanced nutritional and functional properties via higher oxidative stability	[31]

3.3. Blending oils for enhancing nutritional properties

Saturated oils are inherently less susceptible to oxidation in comparison to unsaturated oils, making them more stable. However, their consumption is associated with cardiovascular diseases (CVDs). Therefore, there is a need to promote the consumption of oils with low saturated fatty acid (SFA) content that can still maintain stability under frying conditions. Achieving this balance can be accomplished through the practice of blending oils such as the blending of Chia, flaxseed, sacha inchi, mustard and canola oils that are sources of fatty acid α -linolenic (ω -3) and linoleic (ω -6) [31].

According to the recommendations of the World Health Organization (WHO), the nutritional value of oil is evaluated based on three key factors. The first factor is the presence of antioxidants in the oil, the second factor is the balance between saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids, and the third factor is the ratio of essential fatty acids in the oil. Besides, WHO recommends a ratio of 1:1.5:1 for SFA (saturated fatty acids) to MUFA (monounsaturated fatty acids) to PUFA (polyunsaturated fatty acids). Additionally, the suggested ratio of α -linolenic acid (ω -3) to linoleic acid (ω -6) in dietary intake stands at 1:5-10 are good health and beneficial for people with heart disease, diabetes, and immune response disorders [32]. Given that no single oil perfectly meets all nutritional requirements and possesses an ideal fatty acid profile, the practice of blending vegetable oils emerges as a cost-effective strategy to modify their fatty acid profiles and physicochemical properties [18].

The judicious blending of suitable oils can yield a functional oil with a favorable n-6/n-3 ratio, conducive to improved health [33]. Omega-3 and omega-6 fatty acids are essential components of our diet, necessary for the prevention and treatment of certain diseases [34]. Omega-3 fatty acids play vital roles in normal growth and are associated with the prevention of cardiovascular of cancer diseases, and the enhancement of immune function. While both groups of these essential fatty acids can generate eicosanoid-signaling molecules, however, the omega-6 eicosanoids in the absence of omega-3 counterparts, are typically pro-inflammatory and can contribute to conditions such as obesity, high blood pressure, arthritis, and cardiovascular

diseases. Control of the eicosanoid function of omega fatty acids is related to their balance in the diet [35]. Research has shown that the adulteration of oils can result in improved nutritional and functional characteristics, albeit often with various associated health effects. Blending oils are a prevalent practice for creating novel vegetable oils with sought-after health benefits.

A blend of flaxseed oil and peanut oil has been demonstrated to effectively reduce serum triglyceride levels and low-density lipoprotein cholesterol levels in rats, suggesting its potential as a dietary oil rich in omega-3 fatty acids [36]. The impact of dietary fat on health is contingent on its fatty acid composition. A balanced combination of red palm oil, rice bran oil, tea seed oil, and flaxseed oil has been shown to have advantageous effects on glucolipid metabolism, inflammation, oxidative stress, and bone quality in rats [37].

The blending of oils has the capacity to modify the essential fatty acid ratio, fatty acid composition, as well as the levels of tocopherol and cholesterol. This alteration leads to an enhancement in the activity of antioxidant enzymes, a reduction in hepatic lipid peroxidation, and a decrease in LDL oxidation. The judicious blending of essential oils can result in mixtures with advantageous properties, which can then prevent diseases associated with high saturated fatty acids, such as atherosclerosis, oxidative stress [38]. Certain oils, such as cold-pressed varieties, are recognized as health-promoting products. They serve as rich sources of bioactive lipids and antioxidative phenolic compounds, offering potent radical scavenging activity that can enhance human health [39].

The excessive consumption of cooking oil in contemporary society is commonly attributed to being a primary cause of cardiovascular disease. The impact of cooking oils on health is intricately linked to their fatty acid composition. Recent research has honed in on the examination of blend of oils to enhance their functional properties. Studies indicate that a blend of canola oil, corn oil, olive oil, peanut oil, and sunflower oil, featuring a low n-6/n-3 PUFA (polyunsaturated fatty acid) ratio of 6:1, has the potential to aid in the prevention and control cardiovascular disease (CVD) [38]. Besides, evidence supports the notion that Camellia and blended oils are more effective than soybean oil in increasing serum high-density lipoprotein cholesterol levels and reducing the ratio of low-density lipoprotein to high-density lipoprotein cholesterol in hamsters [39].

Table 3. *Effects of different oil blends on nutritional properties*

Oil blend	Nutritional properties	References
Rapeseed oil : Rice bran oil : Black cumin oil (5:10:20)	The ratio of omega-6/omega-3 raises	[31]
Groundnut oil : Linseed oil (30:70)	Low lipoprotein cholesterol level and decreasing serum triglyceride concentration	[36]
Red palm oil : Rice bran oil : Tea seed oil (20:30:50)	Reduced the serum low-density lipoprotein cholesterol	[37]
Soybean oil : Sea buckthorn oil or Camellia oil or Rice bran oil or Sesame oil or Peanut oil (20:80)	The changes in fatty acids, tocopherols' profile, and minor bioactive lipids	[38]
Canola oil : Corn oil or Olive oil or Peanut oil or Sunflower oil with a low n-6/n-3 PUFA ratio of 6 : 1	Reduced n-6/n-3 levels in plasma, liver and adipose tissues, serum triglycerides (TGs) and decreasing low density lipoprotein cholesterol	[40]
Soybean oil : Camellia oils (8.4:5.6)	Enhancing serum high-density lipoprotein cholesterol and decreasing the ratio of low-density lipoprotein to high-density lipoprotein cholesterol.	[41]
Palm oil : Sunflower oil or soybean oil (35:65)	Down-regulated lipoprotein and cytochrome P450s.	[42]
Canola oil : Palm oil blend (80:20)	Not affect serum total carotenoid and δ -tocopherol but increase α and γ -tocopherol.	[43]

A series of other studies demonstrate the effects of vegetable oil mixtures on health: Such as the combination of Olive Oil: Soybean Oil or Sunflower Oil (70:30 or 86:14) has Hypolipidemic effect. Or mix Rapeseed Oil and Palm Oil (80:20) to help improve the n-3 fatty acid ratio in serum [42], [43].

In summary, blending different vegetable oils provide increased flexibility in meeting specific functional properties or desired nutritional. Blending oils for enhancing nutritional properties are summarized in Table 3.

4. Conclusions

Various oils exhibit diverse physical and chemical properties. The utilization of pure vegetable oil often results in limited functional utility due to its suboptimal oxidative stability and nutritional characteristics, and it frequently falls short in terms of oxidative stability. In contrast, blending represents a straightforward and cost-effective physical process, offering a means to alter the fatty acid composition and enhance the presence of bioactive components and natural antioxidants, creating customized products at affordable price points. Indeed, a multitude of studies have furnished substantial evidence supporting blending as a cost-effective and widely embraced method for achieving oils with balanced fatty acid profiles, improved stability, and higher concentrations of antioxidants and bioactive compounds. The practice of blending vegetable oils has become a widely accepted norm in numerous countries and is expected to remain a prevailing trend in the modern industry, catering to the evolving health and nutritional needs of consumers.

REFERENCES

- [1] C. C. Akoh, *Food lipids: chemistry, nutrition, and biotechnology*. CRC press, 2017.
- [2] World Health Organization, *Cardiovascular diseases fact sheet*, 2005.
- [3] A. Y. Allam, Z. S. Khan, M. S. Bhat, B. Naik, S. A. Wani, S. Rustagi, *et al.*, "Chemical, physical, and technological characteristics of palm olein and canola oil blends," *Journal of Food Quality*, vol. 2023, 2023, doi: 10.1155/2023/6503667.
- [4] K. Sharma, M. Kumar, J. M. Lorenzo, S. Guleria, and S. Saxena, "Manoeuvring the physicochemical and nutritional properties of vegetable oils through blending," *Journal of the American Oil Chemists' Society*, vol. 100, no. 1, pp. 5-24, 2023.
- [5] A. J. Dijkstra and G. V. Duijn, "Vegetable oils: oil production and processing," in *Encyclopedia of Food and Health*, Eindhoven, 2016, pp. 373-380.
- [6] V. Santoro, F. D. Bello, R. Aigotti, D. Gastaldi, F. Romaniello, E. Forte, *et al.*, "Characterization and determination of interesterification markers (triacylglycerol regioisomers) in confectionery oils by liquid chromatography-mass spectrometry," *Foods*, vol. 7, no. 2, 2018, Art. no. 23.
- [7] F. Ramroudi, S. A. Y. Ardakani, A. Dehghani-Tafti, and E. K. Sadrabad, "Investigation of the physicochemical properties of vegetable oils blended with sesame oil and their oxidative stability during frying," *International Journal of Food Science*, vol. 2022, 2022, doi: 10.1155/2022/3165512.
- [8] M. Roiaini, T. Ardiannie, and H. Norhayati, "Physicochemical properties of canola oil, olive oil and palm olein blends," *International Food Research Journal*, vol. 22, no. 3, 2015, Art. no. 1227.
- [9] F. Hashempour-Baltork, M. Torbati, S. Azadmard-Damirchi *et al.*, "Vegetable oil blending: a review of physicochemical, nutritional and health effects," *Trends Food Sci. Technol.*, vol. 57, pp. 52-58, 2016.
- [10] O. I. Mba, M. J. Dumont, and M. Ngadi, "Influence of palm oil, canola oil and blends on characteristics of fried plantain crisps," *British Food Journal*, vol. 117, no. 6, pp. 1793-1807, 2015.
- [11] K. Bhardwaj, N. Verma, R. K. Trivedi, S. Bhardwaj, and N. Shukla, "A novel approach for improvement of oxidative stability of flaxseed oil by blending with palm oil," *Int. J. Adv. Res.*, vol. 3, pp. 1399-1407, 2015.
- [12] M. Choudhary and K. Grover, "Effect of deep-fat frying on physicochemical properties of rice bran oil blends," *IOSR J. Nurs. Health Sci.*, vol. 1, pp. 1-10, 2023.
- [13] Y. Zhao, H. Wu, M. Qu, Y. Liu, D. Wang, H. Yang, *et al.*, "Enhancement of oxidative stability of deep-fried sunflower oil by addition of essential oil of amomum villosum lour," *Antioxidants*, vol. 12, no. 7, 2023, Art. no. 1429.

- [14] J. Bardhan, B. Sahoo, R. Chakraborty, and U. Raychaudhuri, "Effect of addition of rice bran oil extract on the stability of sunflower oil, sesame oil and their blends," *International Food Research Journal*, vol. 21, no. 6, pp. 2293-2298, 2014.
- [15] P. Srivastava and R. P. Singh, "Frying stability evaluation of rice bran oil blended with soybean, mustard and palm olein oils," *Oriental Journal of Chemistry*, vol. 31, no. 3, pp. 1687-1694, 2015.
- [16] A. I. Olagunju, O. S. Adelakun, and M. S. Olawoyin, "The effect of rice bran extract on the quality indices, physicochemical properties and oxidative stability of soybean oil blended with various oils," *Measurement: Food*, vol. 6, 2023, Art. no. 100032.
- [17] S. N. Wang, X. N. Sui, Z. J. Wang, B. K. Qi, L. Z. Jiang, Y. Li, *et al.*, "Improvement in thermal stability of soybean oil by blending with camellia oil during deep fat frying," *European Journal of Lipid Science and Technology*, vol. 118, no. 4, pp. 524-531, 2023.
- [18] A. Dhyani, R. Chopra, and M. A. Garg, "Review on blending of oils and their functional and nutritional benefits," *Chem. Sci. Rev. Lett.*, vol. 27, no. 7, pp. 840-847, 2018.
- [19] M. Sura, V. S. Megavath, A. S. Mohammad, S. Pendyala, M. Kulkarni, A. Sreepureddy, and S. Kuthadi, "Studies of the quality parameters of blended oils and sensory evaluation of gram flour products," *Grain & Oil Science and Technology*, vol. 3, no. 4, pp. 138-145, 2020.
- [20] A. Benbouriche, H. Haddadi-Guemghar, M. Bachir-bey, L. Boulekbache-Makhlouf, S. Hadjal, L. Kouadri, *et al.*, "Improvement of thermo-resistance and quality of soybean oil by blending with cold-pressed oils using simplex lattice mixture design," *OCL*, vol. 29, 2022, Art. no. 33.
- [21] C. Y. Ng, Y. Kamisah, O. Faizah, Z. Jubri, H. M. S. Qodriyah, and K. Jaarin, "Involvement of inflammation and adverse vascular remodelling in the blood pressure raising effect of repeatedly heated palm oil in rats," *International Journal of Vascular Medicine*, vol. 2012, 2012, doi: 10.1155/2012/404025.
- [22] A. Cherif and A. Slama, "Stability and change in fatty acids composition of soybean, corn, and sunflower oils during the heating process," *Journal of Food Quality*, vol. 2022, 2022, doi: 10.1155/2022/6761029.
- [23] M. Kiralan, M. Ulaş, A. Özaydin, N. Özdemir, G. Özkan, A. Bayrak, and M. F. Ramadan, "Blends of cold pressed black cumin oil and sunflower oil with improved stability: A study based on changes in the levels of volatiles, tocopherols and thymoquinone during accelerated oxidation conditions," *Journal of Food Biochemistry*, vol. 41, no. 1, 2017, Art. no. 12272.
- [24] G. A. Cardoso-Ugarte, C. C. Morlán-Palmas, and M. E. Sosa-Morales, "Effect of the addition of basil essential oil on the degradation of palm olein during repeated deep frying of french fries," *Journal of Food Science*, vol. 78, no. 7, pp. 978-984, 2013.
- [25] M. Keshvari, S. Asgary, A. Jafarian-Dehkordi, S. Najafi, and S. M. Ghoreyshi-Yazdi, "Preventive effect of cinnamon essential oil on lipid oxidation of vegetable oil," *ARYA atherosclerosis*, vol. 9, no. 5, pp. 280-286, 2013.
- [26] K. M. Mohamed, R. M. Elsanhoty, and M. F. Hassanien, "Improving thermal stability of high linoleic corn oil by blending with black cumin and coriander oils," *International Journal of Food Properties*, vol. 17, no. 3, pp. 500-510, 2014.
- [27] B. Chugh and K. Dhawan, "Storage studies on mustard oil blends," *Journal of Food Science and Technology*, vol. 51, pp. 762-767, 2014.
- [28] R. Farahmandfar, M. Asnaashari, M. Pourshayegan, S. Maghsoudi, and H. Moniri, "Evaluation of antioxidant properties of lemon verbena (*Lippia citriodora*) essential oil and its capacity in sunflower oil stabilization during storage time," *Food Science & Nutrition*, vol. 6, no. 4, pp. 983-990, 2018.
- [29] L. Torri, P. Bondioli, L. Folegatti, P. Rovellini, M. Piochi, and G. Morini, "Development of Perilla seed oil and extra virgin olive oil blends for nutritional, oxidative stability and consumer acceptance improvements," *Food Chemistry*, vol. 286, pp. 584-591, 2019.
- [30] K. Kittipongpittaya, A. Panya, T. Prasomsri, and P. Sueaphet, "Tropical oil blending and their effects on nutritional content and physicochemical properties during deep fat frying," *Journal of Nutritional Science and Vitaminology*, vol. 66(Supplement), pp. 206-214, 2020.
- [31] E. N. Guiotto, V. Y. Ixtaina, S. M. Nolasco, and M. C. Tomás, "Importance of fatty acid composition and antioxidant content of vegetable oils and their blends on food quality and human health," in *Seed oil: Biological properties, Health Benefits and Commercial Applications*, Nova Science Publishers, 2014, pp. 69-82.

- [32] FAO/WHO, "Interim Summary of Conclusions and Dietary Recommendations on Total Fat & Fatty Acids," Joint FAO/WHO Expert Consultation on Fats and Fatty Acids in Human Nutrition, Geneva, 2008.
- [33] M. Rudzińska, M. M. Hassanein, A. G. Abdel-Razek, K. Ratusz, and A. Siger, "Blends of rapeseed oil with black cumin and rice bran oils for increasing the oxidative stability," *Journal of Food Science and Technology*, vol. 53, pp. 1055-1062, 2016.
- [34] M. B. Schulze, A. M. Miniñane, R. N. M. Saleh, and U. Risérus, "Intake and metabolism of omega-3 and omega-6 polyunsaturated fatty acids: nutritional implications for cardiometabolic diseases," *The Lancet Diabetes & Endocrinology*, vol. 8, no. 11, pp. 915-930, 2020.
- [35] I. Djuricic and P. C. Calder, "Beneficial outcomes of omega-6 and omega-3 polyunsaturated fatty acids on human health: An update for 2021," *Nutrients*, vol. 13, no. 7, 2021, Art. no. 2421.
- [36] M. Sharma and B. R. Lokesh, "Modification of serum and tissue lipids in rats fed with blended and interesterified oils containing groundnut oil with linseed oil," *Journal of Food Biochemistry*, vol. 37, no. 2, pp. 220-230, 2013.
- [37] L. Yang, C. Yang, C. Chu, M. Wan, D. Xu, D. Pan, *et al.*, "Beneficial effects of monounsaturated fatty acid-rich blended oils with an appropriate polyunsaturated/saturated fatty acid ratio and a low n-6/n-3 fatty acid ratio on the health of rats," *Journal of the Science of Food and Agriculture*, vol. 102, no. 15, pp. 7172-7185, 2022.
- [38] Y. Li, W. J. Ma, B. K. Qi, S. Rokayya, D. Li, J. Wang,... and L. Z. Jiang, "Blending of soybean oil with selected vegetable oils: impact on oxidative stability and radical scavenging activity," *Asian Pacific Journal of Cancer Prevention*, vol. 15, no. 6, pp. 2583-2589, 2014.
- [39] A. Prescha, M. Grajzer, M. Dedyk, and H. Grajeta, "The antioxidant activity and oxidative stability of cold-pressed oils," *Journal of the American Oil Chemists' Society*, vol. 91, no. 8, pp. 1291-1301, 2014.
- [40] A. Uriho, S. Yang, X. Tang, C. S. Liu, S. Wang, Y. Cong, *et al.*, "Benefits of blended oil consumption over other sources of lipids on the cardiovascular system in obese rats," *Food & function*, vol. 10, no. 9, pp. 5290-5301, 2019.
- [41] T. Y. Chou, Y. F. Lu, B. S. Inbaraj, and B. H. Chen, "Camelia oil and soybean-camelia oil blend enhance antioxidant activity and cardiovascular protection in hamsters," *Nutrition*, vol. 51, pp. 86-94, 2018.
- [42] K. C. Jan, M. Y. Huang, C. J. Chang, and T. C. Liu, "Hypolipidemic effect of blended oil in hamster: Biochemical analysis and gene expression profiling," *Journal of Food and Nutrition Research*, vol. 4, no. 1, pp. 26-32, 2016.
- [43] K. D. Adeyemi, A. B. Sabow, Z. A. Aghwan, M. Ebrahimi, A. A. Samsudin, A. R. Alimon, and A. Q. Sazili, "Serum fatty acids, biochemical indices and antioxidant status in goats fed canola oil and palm oil blend," *Journal of Animal Science and Technology*, vol. 58, no. 1, pp. 1-11, 2016.