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Investigation of functional and physicochemical properties in sunflower seed oil composited with oleoresins of selected spices during storage and deep frying

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Abstract. The growing demand for nutritious and thermo-stable oils highlights the need for improved alternatives to conventional edible oils. Although sunflower oil is nutritionally rich, its poor oxidative stability limits its use. This study aimed to enhance the oxidative stability of regular sunflower oil (RSO) by flavoring it with bioactive oleoresins from ginger, garlic, cinnamon, nutmeg, cloves, and black pepper. Flavored sunflower oil (FSO) and RSO were evaluated for changes in physicochemical and functional properties, including peroxide value (PV), free fatty acid (FFA), iodine value, saponification value, viscosity, flash/smoke point, moisture, oil-insoluble impurities, antioxidant activity, and total phenolic content. GC-MS and SPME were used for fatty acid profiling. After one week of storage, PV and FFA values were significantly lower in FSO (1.23 mEq/kg and 1.56 %) compared to RSO (1.62 mEq/kg and 2.45 %). FSO showed higher phenolic content (4.49 mg GAE/g) and antioxidant activity (35.71 %). Although both oils showed increased PV and FFA during frying and storage, the rate was slower in FSO, indicating improved stability.

Keywords: sunflower oil, oxidative stability, spices, peroxide value, iodine value.

Classification numbers: 1.4.1, 1.4.4.

1. INTRODUCTION

More than 10 million metric tons, which translates into 8 % of the world's total vegetable oil production (fourth vegetable oil) is Sunflower Oil (SFO) and it is a non-volatile oil, pressed from the seeds of *Helianthus annuus* [1]. SFO is a rich source of Polyunsaturated Fatty Acids (PUFA) which helps to satisfy the essential fatty acids requirement of humans. Approximately SFO contains 85 % unsaturated fatty acids which comprise 14 - 43 % of oleic acids (OA) and 44 - 75 % linoleic acids (LA) in its unsaturated fatty acids content and less than 15 % of saturated fatty acids (SFAs). SFO can be classified in terms of the presence of OA content; 14 - 39 % OA (regular oleic), 43 - 72 % OA (mid oleic), and 75 - 91 % OA (high oleic) [2]. The oxidative

stability of the oil depends on the ratio OA: LA, when it is fractionally high SFO shows greater resistance to rancidity because the availability of monounsaturated OA is higher than the presence of polyunsaturated LA. Despite this, LA is a source of omega-6 fatty acids which is beneficial to human health [3].

SFO is a major source of vitamin E and essential fatty acids; which cannot be synthesized within human cells and must be fulfilled by the diet externally. Hence the consumption of SFO helps to produce prostaglandin which supports the protection and function of the immune, central nerves, and reproductive and cardiovascular systems of the human [4]. The presence of an ample amount of PUFA in the unprocessed oil may support reducing the LDL-Cholesterol levels and reduce the risk of cardiovascular diseases. However, the problem is, that most consumers around the globe may use industrially processed oil for frying purposes; which in some instances hydrogenated to increase the physical and keeping qualities of the oil [5].

SFO can be used as a salad dressing, cooking oil, and to prepare oil-based dressings or mayonnaise. It can be used for deep frying at higher temperatures due to the comparatively high smoke point around 180 - 230 °C. The main issue for the usage of SFO is the lower oxidative stability due to the presence of a greater amount of PUFA [2]. Moreover, the shelf life and the quality of the fried product are significantly affected by the oxidative stability of the oil used for frying. Generally, manufacturers tend to use oil varieties consisting of high oleic acid because it brings oxidative stability to the end product. Hence it is a worthy exercise in improving the stability by implementing innovative techniques because a considerable amount of consumers in the world prefer to have SFO as their oil source [4].

2. MATERIALS AND METHODS

A commercially available Regular Sunflower Oil (RSO) sourced from the Marina Oil Company in Sri Lanka was utilized for the experimental analysis. Oleoresins derived from ginger, garlic, nutmeg, cloves, black pepper, and cinnamon were obtained from a well-established, internationally certified supplier in Sri Lanka (Lakessence, Homagama).

2.1. Preparation of flavored sunflower oil samples

To prepare the flavored sunflower oil, a blend of oleoresins was formulated by combining equal quantities (0.001 g each) of ginger, garlic, cinnamon, nutmeg, cloves, and black pepper in a 1:1:1:1:1:1 ratio. This mixture was thoroughly incorporated into 12 g of RSO to produce the Flavored Sunflower Oil (FSO) samples. The blended samples were transferred into amber-colored bottles to protect them from light exposure and stored under ambient conditions (approximately 27 °C) for subsequent analysis. This research builds upon a prior study [6] that examined the effects of individual oleoresins on oil samples. In contrast, the current study explores the functional and physiochemical properties of oil samples infused with a developed oleoresin blend. All prepared samples were produced in triplicate.

2.2. GC-MS analysis for flavored sunflower oil

One gram (1 g) of the oil samples was weighed using a laboratory grade scale and transferred into 25 ml screw cap test tubes, then 2 ml of toluene, 3 ml of *n*-hexane, and 1.5 ml of sodium methoxide solution (2M) were added to the test tubes (base-catalyzed derivatization), capped and shaken vigorously for the 30 s followed by heating at 50 °C - 70 °C for 5 - 10 min using a hot water bath. Finally to perform acid-catalyzed derivatization 2 ml of HCL (1M) was

added and each sample was stirred gently and allowed to cool down to room temperature. After that 5 ml of distilled water and 4 ml of *n*-hexane were transferred into another 20 ml test tubes which were filled with 0.5 g of anhydrous Na_2SO_4 and allowed to stand for 5 - 10 min. Finally, the prepared fatty acid methyl esters (FAMEs) of the oil samples were transferred into the GC valves using a syringe filter-PTFE (0.25 μm) and 1 μl of it was injected into the GC machine for the investigation. GC-grade reagents purchased from Sigma Aldrich were used for the analysis [7].

Fatty acid profiles of the FAMEs were determined using a Gas Chromatograph (model 7890 A, Agilent Technologies) equipped with a Mass Spectrometer (model 5975 C inert XL El/CI MSD) along with a triple-axis detector. HP-5ms nonpolar column was used and the operating temperature was programmed from 80 °C to 200 °C at the rate of increment 5 °C/min during analysis. Helium was used as the carrier gas, and internal pressure was maintained at 100 kPa. The injector temperature was maintained at 250 °C.

2.3. Analysis of volatile compounds using SPME-GC-MS

Approximately 2 g of each FSO sample was placed in a 20 mL GC vial, sealed tightly with a polytetrafluorethylene (PTFE) septum, and allowed to equilibrate for 3 hours at 30 °C to stabilize the headspace volatiles. After equilibration, an SPME needle was used to pierce the septum, and the fiber was exposed to the headspace volatiles for 40 minutes. The adsorbed volatiles were then thermally desorbed into the injection port of a gas chromatograph. Helium served as the carrier gas at a flow rate of 0.9 mL/min, with the temperature programmed to rise from 80 °C to 200 °C at an incremental rate of 3 °C per minute during the analysis. The volatile compounds were identified by comparing their mass spectra with the ICUSJ standard reference library (Instrument Center, University of Sri Jayewardenepura, Sri Lanka).

2.4. Determination of total phenolic content

The total phenolic content was quantified using a modified version of the colorimetric Folin–Ciocalteu method as described by [8]. A 100 mL aliquot of each sample was added to a test tube, followed by the addition of 5.80 mL of distilled water, 500 mL of Folin–Ciocalteu reagent, and 1,500 mL of sodium carbonate. The resulting mixture was vortexed for 30 seconds and then incubated at 40 °C for 30 minutes. Absorbance measurements were taken at a wavelength of 760 nm using a UV-Vis spectrophotometer. Gallic acid was employed as the reference standard to construct a calibration curve, and the total phenolic content of the samples was expressed as gallic acid equivalents, based on a linear equation derived from the calibration curve [9].

2.5. Determination of DPPH radical scavenging activity (Antioxidant assay)

Antioxidant activity was performed by DPPH radical scavenging protocol as reported by [6] with slight modifications. Thus, 500 μl aliquot of each concentration was mixed with 2500 μl of DPPH working solution in screw-capped 4 ml micro test tubes covered with an Al foil. Thereafter, the mixture was vortexed for 30 seconds and left to react for 30 min in the dark. Finally, the absorbance of oil was measured at 517 nm wavelength using a spectrophotometer.

2.6. Measurement of physicochemical properties

The chemical characteristics, including peroxide value (PV), free fatty acid value (FFA), iodine value (IV), and saponification value (SV), as well as the physical attributes such as

moisture content, percentage of insoluble impurities, smoke point, flash point, specific gravity, and viscosity, were evaluated following standardized protocols. The respective methods used were AOCS Cd 8b-90, AOCS Cd 3d-63, AOCS Cd 1b-87, AOCS Cd 3-25, AOAC 925.10, IUPAC 2.604, AOCS Cc 9a-48, AOCS Cc 9a-48, AOAC 90.212, and AOAC 22.00.

2.7. Assessment of thermal stability

To evaluate thermal stability, 10 g of oil was heated to 170 °C. The temperature was maintained at 170 °C for a duration of 2 hours. Samples were collected every 30 minutes during this period to monitor changes in the oil, particularly with respect to PV and FFA values, as indicators of thermal degradation.

2.8. Evaluation of storage stability

The storage stability of the oils was examined using a rapid aging test. FSO and RSO samples were placed into 36 individual glass bottles and stored in a hot air oven set at 60 °C for 12 weeks. Samples were taken out at weekly intervals over the 12-week period, and storage stability was determined based on changes in PV and FFA levels.

2.9. Statistical analysis

Statistical analyses were performed with the Minitab statistical package (version 17). The mean separation was performed using Fisher's Least Significance Difference (LSD) with a 95 % confidence level. All the measurements were expressed as mean values of triplicates.

3. RESULTS AND DISCUSSION

3.1. Fatty acid profile analysis using GC-MS and SPME-GC-MS analysis

The fatty acid composition of oils is generally determined by GC-MS or GC-FID methods [10]. For the derivatization of fatty acids novel and improved technique was used. A combination of base-catalyzed followed the acid-catalyzed derivatization method was followed. The reason for this combination is to increase the yield of the FAMEs. According to [11], the basic method is not suitable for the derivatization of free fatty acids. Hence the combination of the two methods can improve the efficiency of the analysis. Solid-phase microextraction (SPME) is a microsampling technique that has been widelyused in flavor and fragrance research. It is a solvent-free method that is used to trap flavors and fragrances either from aqueous samples (immersion SPME) or from the vapor space above a liquid or a solid sample (headspace SPME). This analysis was carried out qualitatively to investigate the availability of the major fatty acids and other bioactive compounds.

According to Figures 1, 2, and 3 of the chromatograms for RSO, FSO, and flavor profile based on the reference standard, 7 peaks of FAMEs were identified by GC-MS (Fig. 1), of which 3, 2, and again 2 were saturated (C16:0, C18:0, C20:0), monounsaturated (C16:1n7, C18:1n9) and polyunsaturated fatty acids (C18:2n6, C18:3n3), respectively. eugenol, cinnamaldehyde, piperine, caryophyllene, and 2-propynyl were identified. However, trans isomers were not identified initially in natural oil varieties because they have not undergone thermal stress during manufacturing to form trans fatty acids (TFA). However, some studies have revealed that there is a great potential to form TFA if the oil source contains a high percentage of polyunsaturated fatty acids during deep frying [11].

In chromatograms relevant to Figures 2 and 3 of FSO five bio-active compounds namely

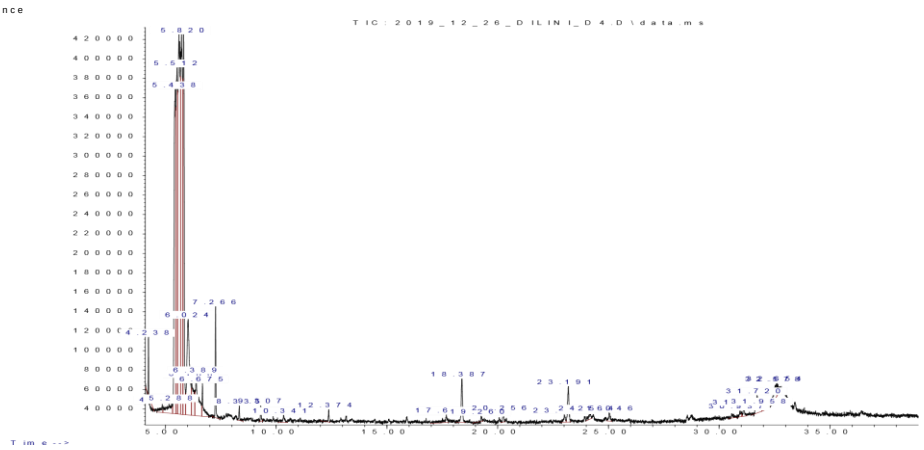

Figure 1. Fatty acid composition of RSO (18.431 = palmitic acid, 31.04 = oleic acid, 32.654 = palmitoleic acid, 33.12 = linoleic acid, 35.62 = linolenic acid, 36.37 = Arachidic acid, 39.9 = stearic acid).

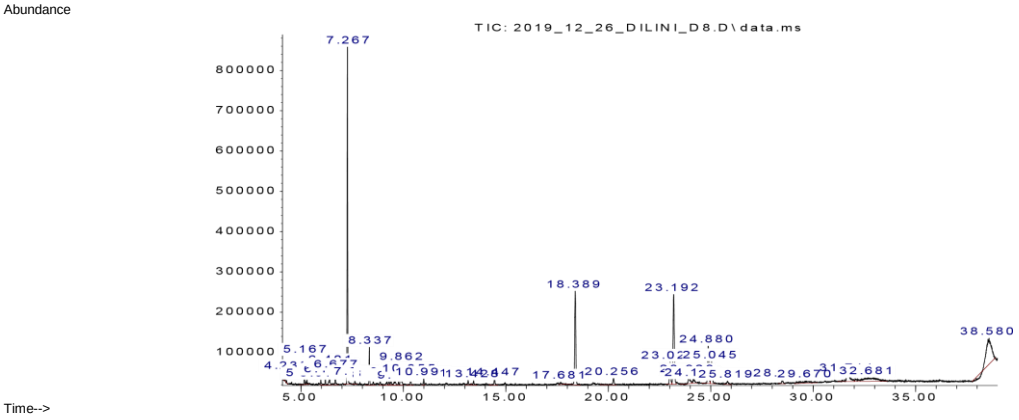

Figure 2. Fatty acid composition of FSO, major fatty acids, and flavor compounds in flavored oil (7.264 = eugenol, 13.424 = cinnamaldehyde, 18.389 = palmitic acid, 28.142 = piperine).

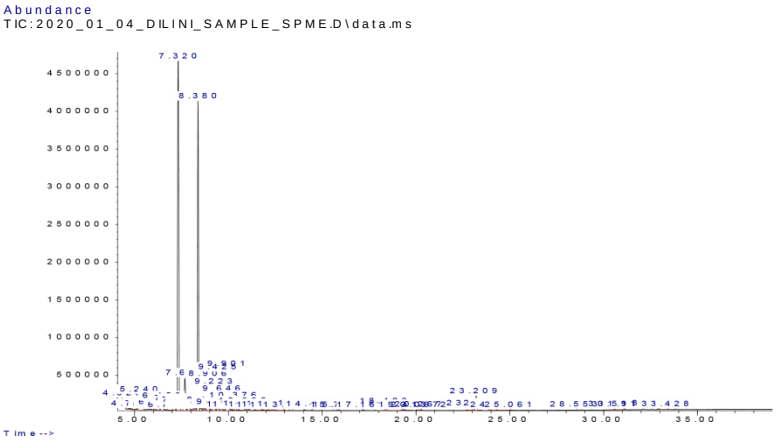

Figure 3. SPME-Flavor profile analysis for FSO (7.320 = phenol,2-methoxy-3-(2-propynyl), 8.380 = caryophyllene, 7.684 = eugenol, 10.424 = cinnamaldehyde, 28.532 = piperine).

3.2. Total phenolic content and antioxidant activity

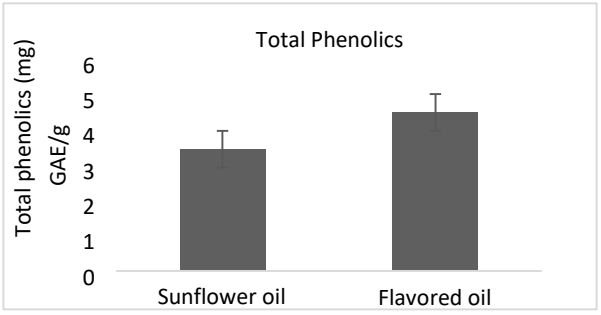

Figure 4. Total phenolics.

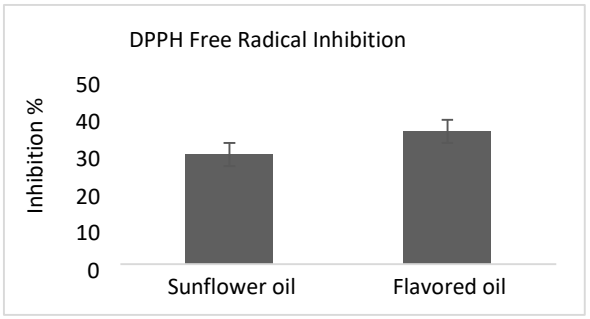

Figure 5. Antioxidant activity.

Total phenolic content (TPC) and antioxidant activity are directly associated with the oxidative stability of oils. The results presented in Figure 4 indicate that the TPC of RSO and FSO oil samples were 3.4 and 4.5 mg GAE/g, respectively. Further, the increment of TPC in FSO is significantly higher than that of RSO ($p < 0.05$). Thus, it indicates that the incorporation of oleoresins in spices greatly contributed to elevating the TPC of sunflower oil. This increment in flavored oil was most probably due to the interactions of phenolic compounds in spices and oil during blending [12]. According to Figure 5, the scavenging effects of flavored oil on DPPH radicals are also significantly higher ($p < 0.05$) than the regular oil samples. This can be attributed to the availability of a considerable amount of phytochemicals including polyphenols in spices which have a high free radical scavenging capacity and peroxide inhibition activity [13]. Researchers have found that there is a strong antioxidant activity in different types of spices. Antioxidant activity via total phenolic content and DPPH free radical scavenging activity on 45 essential oils and also their results disclosed that spices can be used as natural antioxidants to inhibit or postpone the progression of the fat oxidation process [3]. Moreover, the results were in agreement with the findings of [14] who explained that adding garlic extract into oil significantly contributed to increasing TPC content ($p < 0.05$). A similar finding has been reported by [15] stating that the addition of basil extract is capable of increasing the amount of TPC.

3.3. Physicochemical properties of flavored and regular sunflower oil

The evaluation of physicochemical properties is essential in the oil industry as it provides insights into the stability, saturation level, and fatty acid profile of oils. In this study, RSO and FSO samples were analyzed for their physical and chemical characteristics after one week of storage, with the results summarized in Table 1. The PV and FFA values for RSO were recorded as 1.62 ± 0.02 mEq/kg and 2.45 ± 0.01 %, while those for FSO were 1.23 ± 0.01 mEq/kg and 1.56 ± 0.01 %, respectively. A significant reduction in PV and FFA values was observed in FSO compared to RSO ($p < 0.05$), attributed to the presence of spice oleoresins, which are rich in natural antioxidants that inhibit the oxidation process. This observation aligns with findings by [16], which highlight the role of natural plant extracts in preventing lipid oxidation. Similarly, [17] reported decreased PV and FFA levels in flavored oils containing antioxidant-rich plant extracts compared to unflavored samples. Comparable outcomes were also noted by [6], who observed reductions in PV and FFA levels in sunflower oil infused with spices and oleoresins.

Moreover, [18] demonstrated that green and black cardamom could effectively prevent the oxidation of sunflower oil.

Table 1. Physiochemical properties of RSO and FSO.

Parameter	**Regular Sunflower Oil (RSO)**			**Flavored Sunflower Oil (FSO)**		
Peroxide value (mEq/kg)	1.62 ± 0.02			1.23 ± 0.01		
FFA value (%) as oleic acid	2.45 ± 0.01			1.56 ± 0.01		
Saponification value	183 ± 2			190 ± 1		
Iodine value	129 ± 2			133 ± 1		
Moisture (%)	0.1393 ± 0.02			0.1382 ± 0.01		
Insoluble impurities (%)	0.05 ± 0.01			0.05 ± 0.01		
Smoke point (°C)	212 ± 3			220 ± 2		
Flashpoint (°C)	229 ± 2			234 ± 1		
Viscosity (mPa·s)	76.27 ± 0.1			80.72 ± 0.1		
Specific gravity	0.9188 ± 0.002			0.9711 ± 0.001		
Color	L* 74.3 ± 2	a* 1.8 ± 2	b* 7.6 ± 0.5	L* 95.8 ± 2	a* 12.1 ± 2	b* 7.5 ± 0.1

The saponification value (SV), which reflects the average fatty acid chain length, indicated values of 183 ± 2 for RSO and 190 ± 1 for FSO. These values differed significantly ($p < 0.05$). A lower SV typically corresponds to longer fatty acid chains due to fewer carboxylic functional groups per unit mass [19].

The iodine value (IV), which measures oil unsaturation based on the number of double bonds in fatty acid chains, was 129 ± 2 for RSO and 133 ± 1 for FSO. The higher IV of FSO ($p < 0.05$) suggests a greater degree of unsaturation. IV values ranging between 125 - 150 classify oils as semi-drying, meaning they partially harden over time due to autoxidation at the double-bonded carbon atoms during storage. Higher IVs (above 50) in some natural oils may contribute to oxidative rancidity and hardening, rendering them unsuitable for culinary applications. Oils with lower or moderate IVs are generally preferred for thermal food processing [20].

Oil color is a critical parameter influencing consumer preferences. The addition of spice oleoresins resulted in FSO having a darker color compared to RSO due to the dark brown hue of the oleoresins. This change was reflected in the L* value, which dropped from 95.8 ± 2 in RSO to 74.3 ± 2 in FSO. The oleoresins also contributed to an increase in the redness (a*) value and a reciprocal decrease in the yellowness (b*) value. Statistical analysis confirmed significant differences ($p < 0.05$) in the L*, a*, and b* values between RSO and FSO. Similar findings were reported by [21], where color changes in oils were attributed to the accumulation of non-volatile decomposition products, such as oxidized triacylglycerols and FFAs, which can indicate oil deterioration.

The stability of cooking oils during heating and their ability to minimize the emission of potentially toxic volatile organic compounds are critical considerations in the oil industry. The smoke point is defined as the temperature at which oil starts to produce continuous smoke, coinciding with the release of volatile compounds resulting from a low smoke point [22]. In this study, the smoke point and flash point of RSO were measured as 212 ± 3 °C and 229 ± 2 °C, respectively, while those of FSO were recorded as 220 ± 2 °C and 234 ± 1 °C. These results

indicate that both the smoke point and flash point of FSO were significantly higher ($p < 0.05$) than those of RSO. Similar enhancements in the smoke point have been observed in soybean oil and lard with the addition of synthetic antioxidants [23]. These findings suggest that antioxidants can help maintain the smoke point by inhibiting the formation of free fatty acids in oils. Additionally, due to the higher specific heat capacity of spice oleoresins compared to the primary fatty acids in sunflower oil, incorporating oleoresins is likely to raise the smoke point [24].

The viscosity of the RSO and FSO samples, measured after one week of storage at 35 °C, was 76.27 ± 0.1 and 80.72 ± 0.1 mPa·s, respectively. Oil viscosity is influenced by factors such as the type of oil, the presence of triglycerides (TGs), frying temperatures, and overall oil quality [25]. The results, as shown in Table 1, indicate that the viscosity of FSO was significantly higher ($p < 0.05$) than that of RSO. This increase is likely due to the incorporation of various chemical components from the spice oleoresins into the fatty acid matrix of FSO. Similarly, the specific gravity of RSO and FSO samples was measured at 0.9188 ± 0.002 and 0.9711 ± 0.001, respectively, with FSO displaying a significantly higher specific gravity ($p < 0.05$). This difference can be attributed to the addition of spice extracts, which introduce more compact and denser components into the oil compared to pure oils, as noted by [26].

The moisture content in edible oils plays a vital role in lipid oxidation, with an optimal range between 0.05 % and 0.3 % [27]. In this study, the moisture content of RSO and FSO samples was within 0.1 - 0.2 %, falling well within the acceptable range. Insoluble impurities were measured at approximately 0.05 ± 0.01 % in both RSO and FSO samples. However, there were no significant differences in moisture content or insoluble impurities between the two oil samples ($p > 0.05$).

3.4. Thermal stability of oil samples

Assessing the thermal stability of oils and fats is critical as they are commonly used in baking, frying, and roasting, all of which involve high temperatures. During frying, oils are continuously exposed to air, light, and moisture, conditions that significantly accelerate oxidation and degrade oil quality. This degradation process leads to several physicochemical changes, such as oxidation, hydrolysis, polymerization, isomerization, and cyclization [28]. The current study evaluated the thermal stability of FSO, enhanced with a spice mixture, during frying intervals at elevated temperatures.

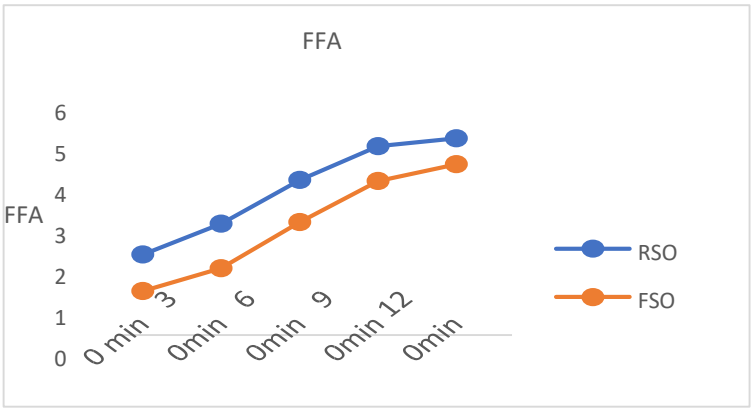

Figure 6. FFA level changes with frying time.

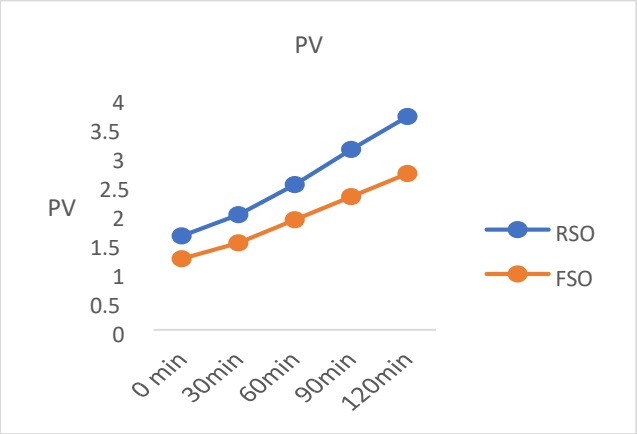

Figure 7. PV changes with frying time.

The peroxide value (PV) serves as an early indicator of rancidity in unsaturated fats and oils, providing a measure of primary oxidation. Higher PV levels suggest that the oil is undergoing oxidative deterioration. Similarly, free fatty acid (FFA) levels indicate hydrolysis and are a key metric of oil quality.

Figures 6 and 7 display changes in FFA levels and PV over frying time, respectively. The results (Figure 6) show that FFA levels increased in all samples during frying, but the rate of increase in FSO was slower compared to RSO. For RSO, the highest FFA value was recorded as 5.31 ± 0.01 after 120 minutes of frying at 170 °C, whereas FSO exhibited a lower value of 4.96 ± 0.01 under the same conditions. Statistical analysis confirmed a significant difference ($p < 0.05$) between the FFA levels of RSO and FSO at all tested temperatures.

The PV also provides critical insights into oxidation levels. All samples demonstrated an upward trend in PV over time; however, the rate of increase in FSO was notably lower than in RSO (Figure 7). A significant difference ($p < 0.05$) was observed between the PV of RSO and FSO throughout the frying process. After 120 minutes at 170 °C, RSO reached a PV of 3.69 ± 0.01, while FSO displayed a lower PV of 2.70 ± 0.01 under identical conditions. The results highlight that FSO consistently exhibited lower FFA and PV levels compared to RSO across the frying period. This difference can likely be attributed to the presence of polyphenols and antioxidants in the spice mixture, which inhibit the initiation and propagation phases of oxidation reactions. Similar findings were reported by [29], who observed reduced oxidative degradation in oils supplemented with spice extracts.

The oxidative stability of RSO at 180 °C intended to estimate the antioxidant activity of four different plant extracts in comparison with butylatedhydroxytoluene (BHT) [30]. According to their results plant extracts were found to be the most potent source of natural antioxidants and they were capable of inhibiting lipid oxidation parameters extensively. The thermal stability of SFO with the addition of clove, pepper, and ginger. Their results also show a similar pattern of FFA and PV increment with the heating time [6].

3.5. Storage stability of oil samples

The addition of antioxidants to oils can significantly enhance their storage stability [9]. In this study, the shelf life of RSO and FSO samples was evaluated based on their PV and FFA levels over a 12 week storage period at 60 °C. Storage conditions play a critical role, as oxidative deterioration accelerates at higher temperatures and under light exposure compared to other

storage environments [31]. Figure 8 demonstrates that the initial FFA level of RSO was marginally higher than that of FSO. Under the accelerated storage condition of 60 °C, all oil samples exhibited a gradual and consistent increase in FFA levels. After 12 weeks, RSO recorded the highest FFA value (9.90 ± 0.01), while FSO showed a comparatively lower FFA level of 7.60 ± 0.01. Although the FFA levels increased across all samples during storage, the rate of increase in FSO was slower than in RSO (Fig. 8). Statistical analysis confirmed a significant difference ($p < 0.05$) between the FFA levels of FSO and RSO at the end of the 12 week storage period.

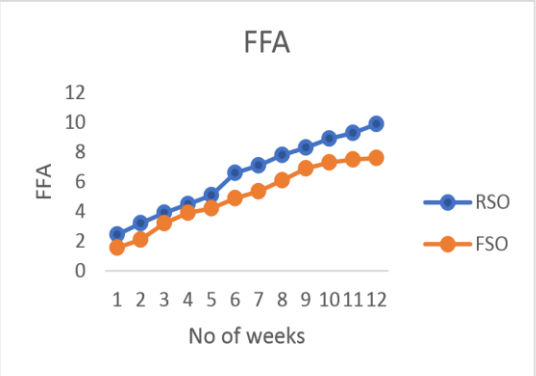

Figure 8. FFA level changes with storage period.

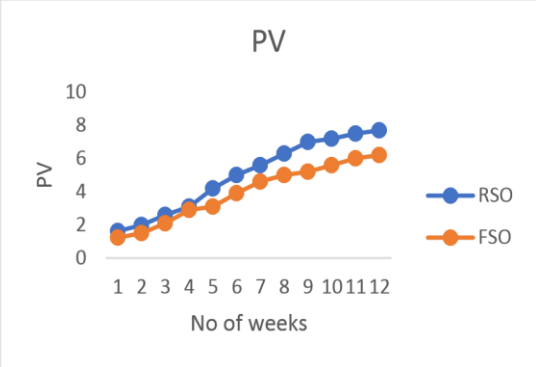

Figure 9. PV changes with storage period.

Figure 9 highlights the changes in PV during the storage period, showing a steady rise in both oil samples. However, FSO displayed a slower rate of PV increase compared to RSO. High PV values reflect the formation of hydroperoxides, an indicator of oil oxidation [21]. By the 12th week, RSO reached the highest PV of 7.70 ± 0.01, whereas FSO exhibited a lower value of 6.20 ± 0.01. Statistical analysis revealed a significant difference ($p<0.05$) in PV between RSO and FSO samples during storage.

The improved storage stability of FSO can likely be attributed to the radical-scavenging properties of the spices incorporated into the oil. A previous study investigating sunflower oil with garlic extract found that FFA levels increased more rapidly in untreated oil compared to garlic-enriched oil [14]. Similarly, research has reported a slower rate of PV increase in sunflower oil when natural antioxidants derived from sesame seed oil were added [32].

4. CONCLUSIONS

The prime objective of this study was to develop flavored sunflower oil by compositing it with extracts of natural spices to enhance the physicochemical and functional properties of raw oil. Though RSO is rich in essential fatty acids and vital vitamins, it possesses poor oxidative stability due to the presence of PUFAs which impart a higher degree of unsaturation. This phenomenon may badly affect the cooking quality of the oil at higher temperatures as well as oil storage. Spices found more in tropical countries, naturally embedded with phenolic compounds, alkaloids, organic acids, saponins, and anti-viral and anti-bacterial compounds which contribute to improving the stability of oil varieties. Results of this study revealed that the thermal stability and storage stability of FSO can relatively be increased by compositing oil with spice extract because these extracts contain natural antioxidants. Further, this study revealed that the PV and FFA of FSO were significantly retarded against the same parameters of RSO. The smoke point

and the flashpoint of FSO were elevated due to the incorporation of spice extract which would aid in carrying out deep frying at high temperatures. A significant increment in total phenolic content and the antioxidant assay was also identified in FSO oil samples. Hence, this flavored sunflower oil with spice extract can be introduced into the commercial market as an alternative to the available oil varieties.

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Declaration of Competing Interests. The authors declare that the research was conducted in the absence of any financial or commercial relationships that could be created as potential conflicts of interest regarding the publication of this paper.

CRediT authorship contribution statement. Dilini N. Perera: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing – original draft, Writing - review & editing. Geeth G. Hewavitharana: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing. S.B. Navaratne: Conceptualization, Writing - review & editing, Resources, Supervision.

ABBREVIATIONS

SFO – Sunflower oil

RSO – Regular sunflower oil

FSO – Flavored sunflower oil

FAME – Fatty acid methyl ester

MUFA – Monounsaturated fatty acid

TG - Triglyceride

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