Research Article

Characterization of Physicochemical Properties of Cooking Oils Sold in Phnom Penh, Cambodia

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Abstract

Cooking oils are prone to degradation through oxidation, leading to a loss of nutritional value and the development of off-flavors causing by the formation of oxidative by-products. The process, marked by reactivity and toxicity, can potentially contribute to health risks such as cancer and inflammation. In the context of Cambodia, cooking oils are currently imported from various countries without a comprehensive assessment of their quality. To address this gap, the present study aimed to assess the physicochemical characteristics of cooking oils available in Phnom Penh's supermarkets. A total of 48 oil samples, sourced from different raw materials and brands, were subjected to extensive analysis to determine their physicochemical attributes. The results revealed a range of findings: peroxide value between 1.69 and 14.55 meq O_2/kg, acid value between 0.11 and 1.62 mg KOH/g, iodine value ranging from 54.12 to 140.00 g I_2/100 g, anisidine value from 19.90 to 138.13, and specific UV extinction at 233 nm and 269 nm varying between 2.30 to 10.82 and 0.32 to 4.36, respectively. Significantly, one sunflower oil sample exhibited a peroxide value exceeding the FAO's Codex Alimentarius Standards, while five oils samples displayed acid value surpassing the recommended FAO limit. Furthermore, the color attributes (L*, a*, and b*) of the cooking oils were measured within ranges of 32.28 to 34.84, -1.75 to -0.15, and 0.93 to 6.83, respectively. These findings underscore the concern that certain cooking oils available in Phnom Penh's supermarkets do not meet the established FAO standards, potentially attributable to factors such as expiration dates, inappropriate transportation, and improper storage conditions.

Introduction

Oils and fats are important parts of human diet as they are rich sources of dietary energy and contain more than twice the caloric value of equivalent amount of sugar [1]. Their functional and textural characteristics contribute to the flavor and palatability of natural and prepared foods [2]. They contain certain fatty acids which play an important role in nutrition and are also carriers of fat-soluble vitamins. Vegetable oils may get rancid and hence lose its nutritional values and favor upon improper extraction process, handling and storage [3]. Moisture, microbes, air, antioxidants, and exposure to sunlight are among factors determining the rancidity or deterioration time of oils [4].

In quality control, several parameters such as iodine value (degree of unsaturation), peroxide value (formation of primary oxidation products), moisture content, specific gravity (purity), and acid value (free fatty acids

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formation because of rancidity) are key parameters of interest as they determine the shelf-life quality and hence the economic value of oils [5]. Rancidity of vegetable oils may pose health risks including cancer and inflammation because of the formation of toxic and reactive oxidation products [5,6]. For healthy consumption, unsaturated oils are better than saturated ones. Consumption of palmitic oil (highly saturated) is associated with an increased risk of developing cardiovascular diseases [7,8]. In contrast, edible vegetable oils such as sunflower, olive, canola and niger-seed oils contain high levels of polyunsaturated fats, which make them susceptible for rancidity [9]. FAO has outlined the quality standards for various constituents of edible vegetable oils, contaminated heavy metals, fatty acid composition, antioxidants, micronutrients, and other physicochemical parameters. The FAO guideline sets the maximum allowable limit for edible oils quality parameters including moisture (0.2%), acid value (0.6 mg potassium hydroxide/g oil) and peroxide value (10 meq O_2/kg oil) [10]. In Cambodia, cooking oils with different types of raw materials and brands are imported from other countries for daily consumption. In addition, their physicochemical quality has not yet been evaluated. Therefore, the purpose of this study was to evaluate the quality of cooking oils sold in the supermarkets in Phnom Penh, Cambodia.

Materials and Methods

Sample preparation

In this study, 48 cooking oil samples with different raw materials and brands were collected from supermarkets in Phnom Penh city, Cambodia. Among 48 oil samples, there were 2 brands of canola oil, 2 brands of coconut oil, 3 brands of corn oil, 1 brand of groundnut oil, 2 brands of palm olein, 4 brands of rice bran oil, 1 brand of sesame oil, 11 brands of soybean oil, 16 brands of sunflower oil, and 6 brands of blended oil. All oil samples were then stored in a dark place at room temperature prior to analysis of their physicochemical quality.

Peroxide value of cooking oils

In this experiment, 5 g of each oil sample were dissolved in 50 mL of acetic acid/chloroform with the ratio of 3:2. The mixture solution was immediately reacted with 0.5 mL of saturated potassium iodide. A volume of 30 mL of distilled water was added into the mixture. The liberated iodine was then titrated with 0.1 M sodium-thiosulphate using 0.5 mL of starch solution as an indicator until the color disappeared. And the blank sample was performed without the sample [11-13]. The peroxide value was then calculated by using the following formula:

$$\text{Peroxide value (meq} O_2/\text{kg oil)} = \frac{(S - B) \times M}{W} \times 1000$$

Where B is the volume of sodium-thiosulphate used for the blank, S is the volume of sodium-thiosulphate consumed by the oil sample, M is the molarity of sodium-thiosulphate, and W is the weight of oil sample.

Acid value (AV) of cooking oils

Five grams of oil sample were mixed with 75 mL of freshly neutralized hot ethyl alcohol. And phenolphthalein was used as an endpoint indicator. The solution was then titrated against 0.1 N of sodium hydroxide until the first pink color appeared which persisted at least 30s [12,13]. The acid value was then calculated as the equation below:

$$\text{Acid value (mg KOH/g oil)} = \frac{V \times N \times 56.1}{W}$$

Where V is the volume of standard KOH solution (mL), N is the normality of standard KOH solution, W is the weight of oil sample in grams, and molecular weight of KOH = 56.1 g/mol.

Iodine value (IV) of cooking oils

A specific amount of oil sample was weighed and put in 500 mL. Then, 15 mL of mixture of cyclohexane and acetic acid (1:1 v/v) and 25 mL of Wijs solution were added. And the blank test was determined without the oil sample. The solution was then shaken and put in a dark place for an hour and 2 hours for the sample obtaining IV<150 and IV>150, respectively. A volume of 20 mL of 10 % KI was added, followed by 100 mL of distilled water. The final content was titrated with 0.1 mol/L sodium-thiosulphate solution using starch as an indicator [13,14]. The iodine value was then calculated as follow:

$$\text{Iodine value (g } I_2/100\text{g oil)} = \frac{12.69 \times (B\text{-}S) \times M}{W}$$

Where B is the volume in mL of standard sodium thiosulphate solution required for the blank, S is the volume in mL of standard sodium thiosulphate solution required for sample, M is the molarity of the standard sodium thiosulphate, and W is the weight in g of the sample.

Anisidine value

A gram of oil sample was dissolved and adjusted the volume to 25 mL using 2,2,4-trimethylpentane. The unreacted test solution was prepared by transferring 5 mL of previous solution into the test tube and 1 mL of glacial acetic acid was added. The solution was incubated in a dark place at 23 °C for 10 min. The solution was transferred to a clear and dry spectrophotometer cell. Absorbance of the unreacted test solution (A0) was determined at 350 nm. The absorbance of reacted test solution (A1) was analysed following the unreacted test solution. But the glacial acetic acid was substituted by anisidine reagent. The absorbance

of blank (A2) was observed according to the reacted test solution method by replacing the sample to 5 mL of iso-octane [12]. The anisidine value of the vegetable oil sample was calculated as following formula:

$$\text{Anisidine value (AnV)} = \frac{100 \times Q \times V \times (1.2A1 \times A2 \times A0)}{m}$$

Where A0 is absorbance of the unreacted test solution, A1 is absorbance of reacted test solution, A2 is absorbance of the blank, Q is sample content (gram/mL, Q is 0.1 g/mL), V equal to 25 mL, the volume in which the test sample is dissolved, 1.2 is the correction factor for the dilution of the 5 mL of test solution with 1 mL of the reagent, and m is mass (g) of the test portion.

Specific UV extinction

The oil sample was weighted 0.12 g to the nearest 0.0001 g and dissolved in 25 mL volumetric flask using iso-octan. The absorbances of the solution were analysed using spectrophotometer at 233, 269, and 446 nm to determine the UV extinction at 233 nm, UV extinction at 269 nm, and carotene content, respectively [12]. The specific UV extinction at 233 nm and 269 nm were calculated as equation below:

$$E(1\%, 233) = \frac{A}{C} - \frac{0.06 \times \text{carotene content} \left(\frac{mg}{kg}\right)}{383}$$

$$E(1\%, 269) = \frac{A}{C} - \frac{0.18 \times \text{carotene content} \left(\frac{mg}{kg}\right)}{383}$$

Where A is absorbance at wavelength (λ), C is concentration of the sample solution (g/100g), carotene content (mg/kg) was examined as follow:

$$\text{Carotene content (mg/kg)} = \frac{383\ E}{I \times C}$$

Where E is absorbance at 446 nm, C is concentration of the solution (g per 100 mL), and I is path length of the cell (cm)

Color

The color of cooking oil samples was determined using Chroma Meter (CR-400, KONICA MINOLTA, Japan). The color parameters were presented as L* (lightness extends from 0 to 100 for black to white, respectively), a* (redness to greenness), and b* (yellowness to blueness). The instrument was standardized using white calibration plate. And the experiments were conducted in triplicate.

Statistical analysis

For all parameters, the experiments were done in triplicate and the values of each parameter were reported in term of mean ± standard deviation (SD). The comparison of mean value was made using analysis of variance ANOVA followed by SPSS with ($p<0.05$) significant level.

Results and Discussion

Peroxide values of cooking oils sold in the supermarkets

Peroxides are the precursors of breakdown products that cause rancid flavors in fat. The concentration of peroxides is indicative of oxidation during the early stages of lipid deterioration. This index becomes less reliable during the later stage of deterioration due to the degradation increase of peroxide [15]. When the peroxide value is between 20 and 40 meq oxygen/kg, the rancid taste begins to be noticeable. Peroxide value is defined as reactive oxygen contents expressed in terms of milliequivalents (meq) of oxygen per kilogram of fat/oil [16]. The peroxide values of cooking oils sold in the supermarkets in Phnom Penh were insignificant differences ($p<0.05$) among various oil brands and oil types. According to figure 1, the peroxide values of blended oil, canola oil, coconut oil, corn oil, groundnut oil, palm olein, rice bran oil, sesame oil, soybean oil, and sunflower oil ranged from 2.57 to 6.19, 3.68 to 5.51, 1,56 to 1.62, 3.38 to 5.99, 5.76, 2.69 to 4.01, 2.61 to 4.71, 3.41, 1.69 to 5.18, and 3.01 to 14.55 meq O_2/Kg oil, respectively. In addition, there was only one sunflower oil sample that contained peroxide value (14.55 meq O_2/Kg oil) higher than FAO's Codex Alimentarius Standards. This sample was already expired but it was still available in the supermarket. The results showed a wide range of peroxide values of cooking oils sold in the supermarkets in Phnom Penh due to the unequal production and expiration date. The high peroxide values were found in soybean oils and sunflower oils may be due to the high unsaturated fatty acid containing [17] while the high peroxide value found in high saturated fatty acid oils close to the expiration date. The lower peroxide value of cooking oil is negatively correlated to saturation of fatty acids. Previous research mentioned that PV should not be above 10 to 20 meq O_2/kg fat to avoid rancidity flavor [18].

Acid values of cooking oils sold in the supermarkets

The acid value is a measurement of the extent to which the glycerides in the oil have been hydrolyzed by lipase action [19]. The glycerides are also hydrolyzed with water in the presence of air possibly bacteria. The decomposition is accelerated by heat and light [20]. The acid values of cooking oil sold in the supermarkets in Phnom Penh are shown in figure 2. There were significant differences ($p<0.05$) of acid values of cooking oils between different brands and types. Acid values of blended oil, canola oil, coconut oil, corn oil, groundnut oil, palm olein, rice bran oil, sesame oil, soybean oil, and sunflower oil ranged from 0.10 to 1.62, 0.12 to 0.14, 0.07 to 0.08, 0.15 to 0.22, 0.22, 0.14 to 0.26, 0.48 to 0.68, 0.56, 0.08 to 0.27, 0.10, 0.93 mg KOH/g oil, respectively. There were 5 out of 48 cooking oils samples which contained acid values higher than FAO's Codex Alimentarius Standard (0.6 mg KOH/g oil). They were sunflower oil 8 (0.93 mg

KOH/g oil), rice bran oil 2 (0.68 mg KOH/g oil), rice bran oil 4 (0.68 mg KOH/g oil), blended oil 2 (1.62 mg KOH/g oil), and sesame oil (0.79 mg KOH/g oil). In addition, high acid values were observed in all rice bran oil samples. The samples with higher acid value than the FAO standard may be caused by the inappropriate conditions during transportation, storage, and distribution which accelerated the hydrolysis of triglycerides. This high acid value can affect the peroxide value due to the peroxides that are the oxidation products of the free fatty acids [21].

Iodine values of cooking oils sold in the supermarkets

Iodine value is used to indicate the degree of unsaturation in vegetable oil/animal fat/methyl ester or average number of double bonds in fats and oils, also known as iodine number [22]. The decrease in iodine value shows the decrease in the number of double bonds and it indicates the lower oxidation of oil. The iodine value indicates the mass of iodine (I_2) in grams that is necessary to completely saturate, by mean of a stoichiometric reaction, the molecules of 100g of a given oil [23]. There were significant differences (p<0.05) of iodine values between oil samples collected from the supermarkets. The iodine values by oil types are also presented in table 1. The results showed that the iodine values of blended oils, canola oils, coconut oils, corn oils, groundnut oil, palm olein

oil, rice bran oil, sesame oil, soybean oils, and sunflower oils sold in the supermarkets in Phnom Penh ranged from 54.12 to 123.21, 110.09 to 113.34, 8.31 to 10.91, 111.31 to 128.54, 104.08, 66.11 to 68.61, 99.81 to 106.97, 112.47, 108.53 to 140.00, and 124.40 to 136.09, respectively. These results agreed with those described by [24,25] which presented the same range of iodine values. The high iodine values were found in soybean oil and sunflower oil due to the high unsaturated fatty acids. The iodine value refers to the saturation of fatty acids which the higher iodine value, the lower saturation of oil [26]. High unsaturated fatty acids are recommended for the healthy consumption over the high saturated fatty acids containing oils [5].

Anisidine values of cooking oils sold in the supermarkets

Anisidine value is a parameter that indicates the secondary oxidation compounds, primarily 2-alkenals and 2,4-alkadienals generated due to hydroperoxide decomposition, and it is more sensitive to unsaturated aldehydes. Anisidine value, as a measure of second oxidation products, is used instead of, or together with peroxide value to indicate the quality of oils. Anisidine value is considered to be more reliable parameter of oxidative rancidity that peroxide value in a long-time storage stability [27]. Anisidine values of different cooking

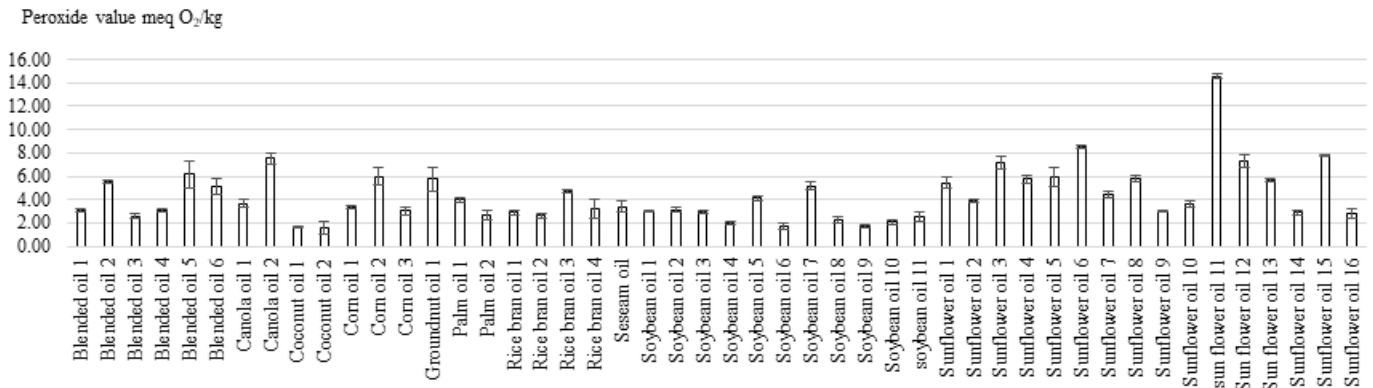**Figure 1:** Peroxide value of cooking oils sold in Cambodian supermarkets.
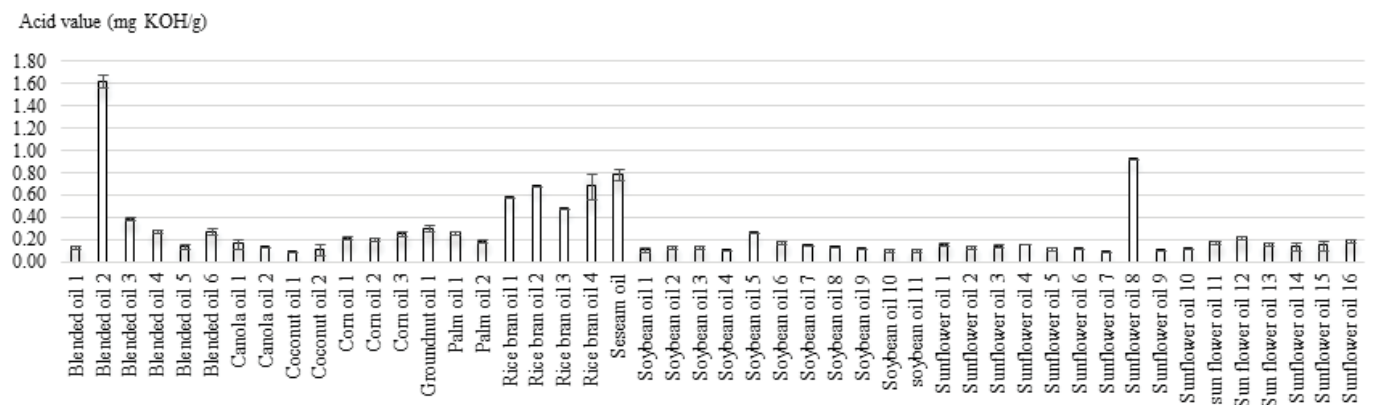
Figure 2: Acid value of cooking oils sold in Cambodian supermarkets.

Citation: Manit Say, Punlork Heng, Sela Kong, Chin Ping Tan, Sivchheng Phal, Yukleav Nat, Reasmey Tan. Characterization of Physicochemical Properties of Cooking Oils Sold in Phnom Penh, Cambodia. Journal of Food Science and Nutrition Research 7 (2024): 28-36.

Table 1: Iodine value, anisidine value, specific UV extinction at 233 nm, and specific UV extinction at 269 nm of the cooking oils sold in Cambodian supermarkets.

Oil types	Iodine value (mg I2/100g)	Anisidine value	Specific UV 233	Specific UV 269
Blended oil 1	110.77 ± 1.24	45.34 ± 1.59	7.19 ± 0.02	1.10 ± 0.00
Blended oil 2	54.12 ± 2.52	37.93 ± 2.41	2.44 ± 0.00	0.49 ± 0.00
Blended oil 3	101.62 ± 3.47	30.64 ± 0.59	5.68 ± 0.00	1.81 ± 0.00
Blended oil 4	88.93 ± 2.41	20.78 ± 1.78	2.30 ± 0.00	0.32 ± 0.00
Blended oil 5	123.21 ± 14.81	34.12 ± 15.40	3.28 ± 0.00	0.77 ± 0.00
Blended oil 6	114.75 ± 6.15	82.06 ± 37.57	5.29 ± 0.01	1.15 ± 0.04
Canola oil 1	110.09 ± 8.0	10.60 ± 3.02	3.07 ± 0.00	0.47 ± 0.00
Canola oil 2	113.34 ± 3.14	46.73 ± 2.42	3.78 ± 0.01	2.11 ± 0.00
Coconut oil 1	10.91 ± 4.88	9.94 ± 0.88	1.12 ± 0.00	0.07 ± 0.00
Coconut oil 2	8.31 ± 6.20	7.11 ± 11.72	1.27 ± 0.00	0.11 ± 0.00
Corn oil 1	111.31 ± 1.57	28.27 ± 2.94	3.60 ± 0.00	1.45 ± 0.00
Corn oil 2	128.54 ± 20.43	39.40 ± 30.76	3.01 ± 0.01	1.37 ± 0.00
Corn oil 3	114.40 ± 16.47	19.95 ± 19.90	2.01 ± 0.00	0.81 ± 0.00
Groundnut oil 1	104.08 ± 6.36	37.58 ± 29.85	3.05 ± 0.00	1.58 ± 0.00
Palm olein 1	68.61 ± 3.50	40.26 ± 1.93	3.34 ± 0.00	0.78 ± 0.00
Palm olein 2	66.11 ± 11.80	33.50 ± 36.37	1.80 ± 0.00	0.54 ± 0.00
Rice bran oil 1	100.09 ± 2.01	39.89 ± 3.41	7.28 ± 0.01	2.76 ± 0.00
Rice bran oil 2	99.81 ± 1.41	62.79 ± 3.76	6.07 ± 0.00	3.08 ± 0.00
Rice bran oil 3	106.97 ± 0.83	51.31 ± 1.96	10.82 ± 0.09	3.24 ± 0.00
Rice bran oil 4	102.82 ± 2.37	132.95 ± 54.21	8.49 ± 0.01	2.14 ± 0.00
Sesame oil	112.47 ± 27.43	32.40 ± 6.45	3.51 ± 0.00	1.02 ± 0.00
Soybean oil 1	120.97 ± 2.27	21.62 ± 2.52	5.69 ± 0.00	1.03 ± 0.00
Soybean oil 2	121.53 ± 2.97	30.77 ± 0.81	4.78 ± 0.00	1.77 ± 0.00
Soybean oil 3	121.34 ± 1.67	51.74 ± 1.60	5.44 ± 0.00	1.89 ± 0.00
Soybean oil 4	125.92 ± 0.63	28.71 ± 2.48	4.20 ± 0.00	2.21 ± 0.00
Soybean oil 5	121.51 ± 0.64	24.86 ± 3.81	8.15 ± 0.01	2.10 ± 0.00
Soybean oil 6	140.00 ± 3.61	37.16 ± 1.94	5.81 ± 0.01	1.64 ± 0.00
Soybean oil 7	108.53 ± 3.03	27.34 ± 3.07	4.59 ± 0.00	1.12 ± 0.00
Soybean oil 8	108.83 ± 0.37	36.60 ± 2.87	4.42 ± 0.00	2.32 ± 0.00
Soybean oil 9	126.30 ± 1.96	30.47 ± 2.28	5.16 ± 0.00	2.23 ± 0.00
Soybean oil 10	109.18 ± 1.04	19.91 ± 5.28	5.26 ± 0.01	1.57 ± 0.00
Soybean oil 11	116.90 ± 5.35	33.98 ± 3.83	3.34 ± 0.01	0.58 ± 0.00
Sunflower oil 1	124.40 ± 0.97	87.17 ± 1.50	5.09 ± 0.00	3.05 ± 0.00
Sunflower oil 2	128.89 ± 2.94	62.50 ± 1.30	4.97 ± 0.00	2.83 ± 0.00
Sunflower oil 3	124.76 ± 1.66	120.06 ± 1.32	5.86 ± 0.01	3.89 ± 0.00
Sunflower oil 4	134.17 ± 1.51	91.37 ± 2.49	3.95 ± 0.00	4.36 ± 0.00
Sunflower oil 5	130.79 ± 1.25	106.33 ± 3.58	4.95 ± 0.00	1.99 ± 0.00
Sunflower oil 6	132.65 ± 4.27	49.35 ± 2.09	5.48 ± 0.00	2.02 ± 0.00
Sunflower oil 7	136.09 ± 1.98	77.51 ± 4.63	4.38 ± 0.00	2.94 ± 0.00
Sunflower oil 8	127.38 ± 2.02	22.62 ± 2.03	5.34 ± 0.00	1.62 ± 0.00
Sunflower oil 9	126.04 ± 3.42	90.44 ± 3.56	6.51 ± 0.01	2.38 ± 0.00
Sunflower oil 10	105.96 ± 1.53	79.47 ± 0.73	5.25 ± 0.00	2.54 ± 0.01
Sunflower oil 11	115.11 ± 1.36	138.13 ± 1.92	10.09 ± 0.04	1.50 ± 0.00
Sunflower oil 12	131.82 ± 4.63	43.40 ± 0.95	5.26 ± 0.00	0.66 ± 0.00
Sunflower oil 13	127.39 ± 3.17	40.29 ± 0.79	4.11 ± 0.00	1.64 ± 0.00
Sunflower oil 14	123.14 ± 4.52	103.93 ± 11.88	2.69 ± 0.00	1.38 ± 0.00
Sunflower oil 15	131.68 ± 5.00	47.07 ± 24.69	3.21 ± 0.02	0.72 ± 0.00
Sunflower oil 16	118.63 ± 16.56	93.64 ± 6.77	3.89 ± 0.01	0.63 ± 0.00

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oils are presented in table 1. The means of anisidine values between oil brands showed significant difference ($p<0.05$). The anisidine values of blended oil, canola oil, coconut oil, corn oil, groundnut oil, palm olein, rice bran oil, sesame oil, soybean oil, and sunflower oil ranged from 20.78 to 82.06, 10.60 to 46.73, 7.11 to 9.94, 19.95 to 39.40, 37.58, 33.05 to 40.25, 39.89 to 132.95, 32.40, 19.90 to 37.16, 22.61 to 138.13, respectively. The high anisidine value of cooking oils sold in the supermarkets due to the breakdown of peroxides and hydroperoxide [28,29]. Even though the anisidine value is considered to be more reliable parameter than peroxide value, but peroxide value still show fair correlations with the sensory parameters such as aroma, flavor, aftertaste of the samples while acid value showed no correlations [30].

Specific UV extinction of cooking oils sold in the supermarkets

The absorbance at ultra-violet wavelengths of the cooking oil products provides an indication of deterioration and purity of the oil product. In the ultra-violet region, the autoxidation products of fats and oils present the spectra characteristics: hydroperoxide and conjugated dienes from decomposition were detected at 233 nm, while the secondary products of autoxidation and ethylenic diketone were detected at 268 nm. The determination of absorbance in cooking oils can provide the indication of the state of autoxidation [12,31]. The specific UV extinctions of cooking oils at 233 nm and 269 nm are presented in table 1. There were significant differences ($p<0.05$) of specific UV extinction at 233 nm and 269 nm between cooking oils sold in the supermarkets in Phnom Penh. This high content of hydroperoxide, conjugated dienes, secondary products of autoxidation, and ethylenic diketone may be caused by the oil's decomposition and autoxidation [32].

Color of cooking oils sold in the supermarkets

Color is an important parameter of edible oil, both in the refining process and in the marketplace. Oil appearance might be an indicator of the problems having occurred during processing and storage. The color of the oil samples is shown

Table 2: Color of cooking oils sold in Cambodian supermarkets.

Oil types	L*	a*	b*
Blended oil 1	32.83 ± 0.67	-0.31 ± 0.05	1.53 ± 0.23
Blended oil 2	32.50 ± 0.86	-1.56 ± 0.09	5.69 ± 0.21
Blended oil 3	33.56 ± 1.09	-0.71 ± 0.02	2.46 ± 0.23
Blended oil 4	32.74 ± 0.99	-1.37 ± 0.02	4.94 ± 0.14
Blended oil 5	33.17 ± 0.53	-0.01 ± 0.05	1.44 ± 0.03
Blended oil 6	33.14 ± 0.79	-0.42 ± 0.06	1.77 ± 0.14
Canola oil 1	32.71 ± 0.52	-0.44 ± 0.11	2.08 ± 0.15
Canola oil 2	33.40 ± 0.66	-0.51 ± 0.05	2.29 ± 0.13
Coconut oil 1	32.26 ± 0.39	-0.24 ± 0.07	1.58 ± 0.05
Coconut oil 2	30.60 ± 5.87	-0.03 ± 0.02	1.36 ± 0.15
Corn oil 1	33.61 ± 0.91	-1.31 ± 0.09	4.62 ± 0.18
Corn oil 2	31.94 ± 0.64	-0.49 ± 0.05	3.18 ± 0.23
Corn oil 3	31.91 ± 0.58	-0.85 ± 0.03	3.83 ± 0.23
Groundnut oil 1	31.00 ± 0.11	-0.55 ± 0.02	3.03 ± 0.10
Palm olein 1	2.65 ± 0.83	-1.49 ± 0.17	5.25 ± 0.51
Palm olein 2	32.57 ± 0.44	-1.28 ± 0.06	5.15 ± 0.12
Rice bran oil 1	32.38 ± 0.82	-1.17 ± 0.09	4.84 ± 0.18
Rice bran oil 2	32.89 ± 0.83	-1.69 ± 0.07	6.84 ± 0.35
Rice bran oil 3	33.39 ± 1.08	-1.76 ± 0.09	6.27 ± 0.15
Rice bran oil 4	33.08 ± 0.32	-2.10 ± 0.01	8.20 ± 0.15
Sesame oil	30.98 ± 0.43	-0.73 ± 0.06	13.11 ± 0.44
Soybean oil 1	33.06 ± 0.14	-0.36 ± 0.06	1.77 ± 0.25

Soybean oil 2	32.71 ± 0.24	-0.66 ± 0.05	2.54 ± 0.20
Soybean oil 3	33.40 ± 0.49	-0.51 ± 0.03	1.80 ± 0.23
Soybean oil 4	33.22 ± 0.49	-0.45 ± 0.06	1.64 ± 0.11
Soybean oil 5	33.23 ± 0.65	-0.37 ± 0.03	1.76 ± 0.03
Soybean oil 6	33.36 ± 0.89	-0.59 ± 0.08	2.02 ± 0.16
Soybean oil 7	33.19 ± 0.62	-0.41 ± 0.09	1.58 ± 0.10
Soybean oil 8	32.98 ± 0.54	-0.38 ± 0.06	1.90 ± 0.15
Soybean oil 9	32.95 ± 0.41	-0.69 ± 0.02	2.15 ± 0.21
Soybean oil 10	33.61 ± 0.80	-0.61 ± 0.08	2.11 ± 0.19
Soybean oil 11	32.44 ± 0.81	-0.26 ±0.07	2.08 ± 0.12
Sunflower oil 1	33.64 ± 0.10	-0.91 ± 0.03	4.47 ± 0.03
Sunflower oil 2	34.42 ± 0.18	-0.34 ± 0.05	1.50 ± 0.23
Sunflower oil 3	34.70 ± 1.03	-0.28 ± 0.07	1.28 ± 0.23
Sunflower oil 4	34.85 ± 1.01	-0.42 ± 0.04	1.68 ± 0.22
Sunflower oil 5	34.80 ± 0.98	-0.36 ± 0.07	1.37 ± 0.29
Sunflower oil 6	33.37 ± 0.61	-0.16 ± 0.01	0.93 ± 0.07
Sunflower oil 7	33.20 ± 0.73	-0.42 ± 0.03	1.40 ± 0.12
Sunflower oil 8	33.44 ± 0.62	-0.34 ± 0.05	1.63 ± 0.17
Sunflower oil 9	33.27 ± 0.82	-0.27 ± 0.05	1.25 ± 0.01
Sunflower oil 10	33.53 ± 0.70	-0.44 ± 0.05	1.51 ± 0.15
Sunflower oil 11	33.94 ± 1.15	-0.21 ± 0.07	1.56 ± 0.16
Sunflower oil 12	33.48 ± 0.94	-0.29 ± 0.06	1.06 ± 0.16
Sunflower oil 13	33.33 ± 0.34	-0.42 ± 0.04	1.73 ± 0.09
Sunflower oil 14	33.18 ± 0.55	-0.30 ± 0.04	1.82 ± 0.08
Sunflower oil 15	33.03 ± 0.68	-0.15 ± 0.04	1.59 ± 0.16
Sunflower oil 16	31.93 ± 0.30	-0.59 ± 0.01	2.48 ± 0.15

in table 2. The color (L*, a*, and b*) of cooking oils sold in the supermarkets in Phnom Penh was significant difference ($p<0.05$) between oil brands and oil types. The lightness and a* (green – red) of all cooking oils were in a narrow range while b* (blue – yellow) was in a wide range. The color of the cooking oil is due to carotenoids and other pigments while the formation of polymers and combination of peroxide and aldehyde will affect the redness and yellowness, respectively [33]. The difference of color in cooking oil may be due to the oil types, degree of oil refinery, and storage conditions [34,35].

Conclusion

In the context of cooking oils available in Phnom Penh's supermarkets, a noteworthy proportion displayed elevated peroxide values, indicative of advanced rancidity. Among the forty-eight samples evaluated, fifteen exhibited rancidity levels surpassing half of the FAO standard. In addition, five samples surpassed the FAO standard for acid values. Intriguingly, these deviations were not inherently tied to oil types, suggesting that production and expiration date disparities played a role. The observed high anisidine values were likely influenced by the high peroxide value. Subtle variations in color were possibly attributed to oil types, pigments, and refining processes. The broad spectrum of physicochemical qualities observed can be attributed to inappropriate transportation, storage, and on-shelf conditions. For consumers, seeking optimal cooking oils, prioritizing a substantial period before the expiration date emerges as a pivotal factor in making informed purchasing decision.

Acknowledgement

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