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Quality assessment of Commercially Refined Sunflower Oil found in the Market of Pokhara, Nepal

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Abstract

Sunflower oil is widely used for home cooking and the food industry. Food safety concerns are always there while consuming oil daily, so people want their purchased and consumed oil to be safe. The main aim of the research is to demonstrate and compare the data of different parameters obtained from laboratory experiments following the standard methods suggested by FSSAI-2016 (Food Safety and Standard Authority of India), A.O.A.C. (Association of Analytical Chemists) and the standard values given by D.F.T.Q.C. (Department of Food Technology and Quality Control), Nepal in 2075 B.S for edibleness of sunflower oil. Here, we show the standard methods to test the different parameters, i.e., moisture content, acid value, density, peroxide value, iodine value, saponification value, and unsaponifiable matter of edible sunflower oil. The dataset of preliminary and physiochemical analysis were within the limits of D.F.T.Q.C. standards for edible and refined sunflower oil, where moisture content was 0.05±0.01, refractive index was 1.4676±5.7735E-05, peroxide value was 2.65±0.098, acid value was 0.071±0.0026, iodine value was 128.02±0.007, saponification value was 189.92±1.094 and unsaponifiable matter was 2.53±0.7. This study concludes that all the selected samples of sunflower oils are in the permissible range according to the D.F.T.Q.C. directory (2075). It indicated that selected sunflower oil types have regulatory standards for public consumption concerning health risks under study from the Pokhara market.

Keywords Sunflower oil, Oil analysis, Parameter, D.F.T.Q.C., A.O.A.C., F.S.S.A.I.

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Introduction

After virgin olive oil, sunflower *(Helianthus annuus L.)* seed oil is the second most widely produced virgin oil in Europe. The oil is well known for having a high level of the lipophilic vitamin alpha-tocopherol, which is known for its antioxidant qualities (Vitamin E) [1]. There are three different varieties of sunflower oil - low, mid, and high oleic - which are identified by the quantity of oleic acid they contain. Nutritional advice advocating the substitution of mono-unsaturated fatty acids, particularly oleic acid, with more oxidizable n-6 fatty acids, such as linoleic acid, has made the high oleic version increasingly prominent. The goal of this change is to reduce the risk of atherosclerosis (2). Cold-pressed oils, obtained solely through mechanical methods like expelling or pressing, maintain their original properties without heat alteration. These oils might undergo purification through water washing, settling, filtering, and centrifuging. Conversely, sunflower seeds are typically processed in large oil mills utilizing solvents for oil extraction, followed by refining processes involving neutralization, bleaching, and deodorization, resulting in refined sunflower oil [3].

Refined sunflower oil, especially high-oleic, is very versatile and due to its neutral flavor and heat stability, it can be used in many ways in the kitchen, such as frying, cooking, or as an ingredient (in mayonnaise) [4]. Good oxidative stability and a superior fatty acid content are characteristics of high-oleic sunflower oil, particularly abundant in oleic acid, an unsaturated fatty acid with greater oxidative stability than other fatty acids [5]. Richer in oleic acid than linoleic and linolenic acid, these oils are less prone to breakdown and release less harmful aldehydes. Moreover, oleic acid-rich oils cause oxidative rancidity during storage or break down gradually when frying. Additionally, consuming oils high in oleic acid has many health benefits, including lowered blood cholesterol and cholesterol buildup in blood vessels as well as increased levels of high-density lipoprotein, which can promote cardiovascular health [6]. Excess linoleic acid has supported tumor growth in animals, also risk in humans, or progression of cancers of the breast and colon [7]. Although diets typically contain small levels of saturated fats, different analyses have revealed a strong connection between high blood pressure, a risk factor for cardiovascular illnesses, and the intake of

saturated fats [8]. Replacing saturated fats with monounsaturated and polyunsaturated fats is good for health. Sunflower oils are excellent providers of polyunsaturated fats, consuming non-hydrogenated unsaturated oils, such as sunflower, is better for reducing health risks [7].

Sunflower oil is predominantly composed of triglycerides, specifically containing various fatty acids such as monounsaturated (oleic acid, about 20-30%), polyunsaturated (linoleic acid, around 60-70%), and saturated (palmitic acid and stearic acid, about 10-15%) fats. Additionally, sunflower oil may contain minor components such as tocopherols (Vitamin E), sterols, and other antioxidants, which contribute to its stability and health benefits [9]. Fatty acid composition and physical and chemical properties are important for oil quality. High Alpha-tocopherols enhance the nutritional value of sunflower oil as a vitamin E source [10]. Oxidation stands as the primary deteriorative process affecting lipids, significantly impacting the quality of fats and oils. Particularly during storage, autoxidation leads to off-flavors, a significant outcome of this process. Unsaturated fatty acids are notably vulnerable to oxidation. Well-established in this phenomenon is the generation of volatile aldehydes, such as E-2-heptenal, identifiable by their extremely low odor thresholds and their role in creating unpleasant rancid or fried odors [11].

Sunflower oil production and refining can have significant environmental impacts, including land use for cultivation, water consumption, pesticide and fertilizer application, and energy use during processing. These practices can lead to soil degradation, water pollution, and greenhouse gas emissions [12,13]. However, some food manufacturers are adopting sustainability practices to mitigate these effects. These practices include using organic farming methods to reduce chemical inputs, implementing crop rotation to maintain soil health, optimizing water usage through efficient irrigation systems, and investing in renewable energy sources for processing facilities. Additionally, some brands are focusing on reducing waste by utilizing by-products and improving packaging sustainability [14–17]. In the context of Nepal, there is no data on the practices of commercial oil producers.

Most of the fatty acids, vitamin E, and certain phytochemicals required in a daily human diet to support essential physiological functions can be found in edible vegetable oils. The Food Safety and Standard Authority of India (FSSAI) monitors commercial oil quality in India and has a manual for testing published in 2016 AD. International standards and guidelines influence Nepal's regulatory framework for edible oils. The quality of edible oils in Nepal is governed by regulatory frameworks and agencies such as the Department of Food Technology and Quality Control (DFTQC), Food Act, 2023 (1967), and Food Regulation, 2027 (1970). The DFTQC, which works under the Nepal Ministry of Agriculture, is responsible for monitoring food products. DFTQC has provided standard values for quality assessment but has not yet provided a procedure manual. The standard parameters of edible sunflower oil provided by DFTQC are given in **Table 1**. In 2019, the DFTQC introduced regulations to limit trans fatty acids in edible oils, aiming to reduce the risk of cardiovascular diseases. The permissible limit for trans fats in edible oils was set at 2% of the total fat content.

Several studies have shown that during the production and refining process, sunflower oil loses considerable amounts of minor components that have nutritional and health benefits [18].

Table 1 Standard parameters of edible sunflower oil (D.F.T.Q.C, 2075; F.S.S.A.I, 2016; codex alimentarius FAO-WHO, n.d.)

Parameters	Acceptable Value (DFTQC)	Acceptable Value (FAO/WHO)	Acceptable Value (FSSAI)
Moisture and volatile matter at 105 °C	Less than 0.1%	Less than 0.2%	Not Found
Refractive index at 40 °C	1.466-1.469	1.461-1.475	1.4640 - 1.4691
Specific Gravity	0.918	0.918	Not Found
Acid value	Less than 0.5 mg KOH/g	Less than 0.6 mg KOH/g	Not more than 6.0
Peroxide value	Less than 10 mileq. peroxide oxygen/kg	Up to 10 mileq of active oxygen/kg	Not Found
Iodine value	110-143	118-141	100-145
Saponification value	188-194	182-194	188-194
Unsaponifiable matter	Less than 15 g/kg	Less than 15 g/kg	Not more than 1.5 per cent
Free fatty acid (%)	Less than 0.25	0.3	Less than 3.01
Ester value (mgKOH/g)	187.5-193.5	181.5-193.5	187.5-193.5
Glycerol (%)	10.26-10.58	9.93-10.58	10.26-10.58

Aside from changes in taste, color, and odor, potential physicochemical changes in oils, such as oxidation and hydrolysis, changes in acidity index, peroxide index, and refractive index, can result in the production of toxic compounds like peroxides, aldehydes, ketones, free radicals, and trans fatty acids, that are harmful to human health. These hazardous substances can develop cancer, arthritis, and accelerated aging in addition to cardiovascular ailments [19]. The products of lipid oxidation (free radicals, polar molecules, flavoring compounds, long-chain fatty acids, organic acids, and other volatile substances) can have an impact on nutritional qualities as well as pose a risk to consumer health [20]. As sunflower oil is refined, its free fatty acid concentration, peroxide value, and wax content can decrease. Compounds such as phosphatides, free fatty acids, odorous volatiles, colorants, waxes, and metal compounds have a detrimental effect on the refined oil's flavor, smell, appearance, and stability during storage [21].

Studies analyzing commercially available oil in Nepal are rare. A previous study, analyzing the quality of selected edible vegetable oils from Damak, Nepal, found that not all vegetable oils meet the criteria set by DFTQC [22]. Out of the 6 analyzed samples, one was sunflower seed oil which met only 9 tested criteria out of 13. A study of physicochemical parameters of sunflower oil from Tansen, and Baglung found that the sunflower oil samples are of acceptable grade and are safe for consumption by humans [23,24]. Here, we investigate the quality of oil from the market of Pokhara, Nepal and determine the parameters outlined by DFTQC.

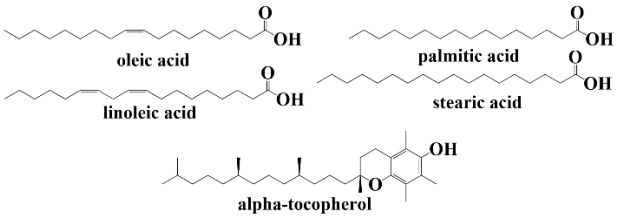

Figure 1: Major chemical constituents in sunflower oil

Materials and Method

Sample collection

Three different brands of sunflower oil were purchased from departmental stores inside Pokhara Valley in 2022. Sunflower oil purchased from the market was transported to the 'Gandaki Province Academy of Science and Technology's Laboratory. Edible vegetable oils of different brands were randomly purchased from the market. For each of the three brands of edible cooking oil, we collected a total of 9 samples. This resulted in 3 samples per brand from three different department stores. In total, 27 samples were tested (3 brands x 3 stores x 3 samples per store). All oil samples were stored in air-tight containers at 4°C in the dark to prevent air contact and direct sunlight to avoid oxidation.

Determination of Physical Parameters

All the analyses such as peroxide value, acid value, moisture content, unsaponifiable matter, saponification value, specific density, and refractive index were performed according to the 'Manual of Methods of Analysis of Food' published by the Food Safety and Standard Authority of India-2016 [25]. The procedure included in the manual follows the standard method recommended by 'The Association of Analytical Chemists'(A.O.A.C.). The experimental values were compared to the standard values provided by the directory of DFTQC-2075.

To ensure the reliability and accuracy of our data, we followed established protocols and implemented quality control measures throughout the analysis process. We included control samples in each batch of analyses to monitor the consistency and accuracy of our testing procedures. These control samples were prepared using known concentrations of analytes to serve as benchmarks. Both positive and negative controls were utilized. Positive controls contained known quantities of the target analytes, while negative controls contained none, ensuring no contamination or false positives. Each sample was tested in triplicate to ensure reproducibility and reliability of the results. The average value of these replicates was used for data analysis. All analytical instruments were calibrated regularly according to the manufacturer's instructions. We followed detailed Standard Operating Procedures (SOPs) for each analytical method to maintain consistency and reliability across all analyses. SOPs included specific guidelines for sample preparation, instrument operation, data recording, and result interpretation.

Determination of Refractive index

Refractive index measurement was done using ABBE'S refractometer by the A.O.A.C. method [26]. The sample (1 mL) was filtered through a filter paper to remove impurities and traces of moisture. A stream of water was circulated through the instrument. The temperature of the refractometer was adjusted to 40°C. The prisms were ensured to be clean and dry. The sample (1 µL) were placed on the prism. The prisms were closed and allowed to stand for 90 s. The oil was rendered optically clear and free from water before the determination. The space between the two prisms was filled with oil and the

thermometer of the instrument (refractometer) was allowed to be at a constant room temperature for 10 min before the reading was taken. This was done at room temperature. Three determinations were carried out for each sample [27].

The refractive index at the specified temperature can use the following formula:

$R = R^1 + K (T^1 - T)$

Here,

R = reading of the refractometer reduced to the specified temperature T °C

R^1 = Reading at T^1 °C

K = constant 0.000365 for fats and 0.000385 for oils (If Abbe Refractometer is used) or = 0.55 for fats and 0.58 for oils (if Butyro-refractometer is used)

T^1 = temperature at which the reading R^1 is taken and

T = specified temperature (generally 40 °C).

Determination of Moisture content

The moisture content was determined according to the Handbook of Food Analysis [26] through desiccation in an oven. For this purpose, 5-10 g of a sample was weighed in a petri dish and placed in an oven with circulating air at 105 °C for 2 h until the constant weight, after which they were taken out, allowed to cool at room temperature, and weighed again.

$$\text{Moisture and volatile matter} = \frac{(W_1 - W_2)}{W_1} \times 100$$

Here,

W_1 = Initial Weight (g)

W_2 = Final weight (g)

Determination of Specific Gravity

Specific gravity was determined by the standard method of A.O.A.C 17th edition, 2000 [26]. The dry pycnometer was filled with the sample in such a manner as to prevent the entrapment of air bubbles after removing the cap of the side arm. The stopper was inserted and immersed in a water bath at 30±2 °C and held for 30 min. Oil coming out of the capillary opening was wiped off to exclude weight of oil that was spilled outside pycnometer to deny false reading. The bottle was removed from water bath, followed by cleaning and drying it. The cap of the side arm was also removed and weighed quickly to ensure that the temperature did not fall below 30 °C.

$$\text{Specific Gravity} = \frac{A-B}{C-B}$$

where,

A = weight in g of specific gravity bottle with oil at 30 °C

B = weight in g of specific gravity bottle at 30 °C

C = weight in g of specific gravity bottle with water at 30 °C

Determination of Acid Value

The acid value was determined by the Manual of FSSAI-2016 [25]. Sample (20 g) was weighed in a conical flask. Analytical-grade ethanol (50 mL) was poured into another conical flask, and a few drops of phenolphthalein indicator were added. Neutralization titration was performed by adding 0.1N NaOH till a light pink was observed. Neutralized ethanol was added to the flask containing oil. The mixture was boiled to prevent dissolving. Titration was done by adding a few drops of phenolphthalein indicator. NaOH solution (0.1N) was added till the appearance of white-pink.

$$\text{Acid Value (AV)} = \frac{MW_{NaOH} \times N \times V}{W_s}$$

Here,

MW_{NaOH} = Molecular weight of NaOH= 40.01

N = Normality of NaOH

V = Volume of NaOH consumed from burette readings

W_s = weight of sample taken

Determination of Peroxide Value

Peroxide values were determined according to A.O.C.S. Official Method Cd 8-53 [28). Weight of the sample (in a range of 10-20 g) was recorded. Thirty milliliters of acetic acid: chloroform (3:2) solution was poured into the flask containing oil. Saturated KI (10 mL) solution was added and shaken well. Subsequently, 30 mL of distilled water was added and shaken again. Titration was done by taking 0.01N sodium thiosulfate solution in the burette and using 0.5 mL of 1% starch solution as an indicator. Titration was done until the black color was removed, and the final reading was noted.

$$\text{Peroxide Value} = \frac{V \times N \times 1000}{W_s}$$

Here,

W_s = sample weight

V= burette readings

N = normality of Sodium Thio. Solution.

Determination of Saponification Value

A.O.C.S. method Cd 3-25 was used to determine the saponification value of oil samples [29]. Approximately, 5 g of oil sample was weighed in the flask, and 50 mL of 4% ethanolic KO2H. was poured into the sample flask. Similarly, 50 mL of 4% ethanolic KOH. was poured into the blank flask. The sample flask was refluxed for 30 min using a reflux condenser until it became a transparent mixture with no layer separation. Similarly, reflux was performed in the blank sample as well. Burettes were filled with 0.5N HCl, and titration was performed separately for the blank flask and sample flask using a

phenolphthalein indicator on both until the disappearance of the pink color.

$$\text{Saponification Value (SV)} = \frac{56.1 \times (V_b - V_s) \times N}{W_s}$$

where,

W_s = Sample weight

V_b = Burette readings from blank titration

V_s =Burette readings from sample titration

N = Normality of HCl

Determination of iodine value

The iodine value was determined by the A.O.C.S. method Cd 1-25 [29]. According to the expected iodine value (0.2538-0.31373)g of sunflower oil was weighed. Carbon tetrachloride (25 mL) was poured into the sample flask, and the stopper was closed immediately. Similarly, the same amount of CCl_4 was added to the blank flask. Wij's solutions (25 mL) was poured into the sample and blank flask. The stopper was closed immediately and shaken well. Potassium iodide crystals were added on all round surfaces of the sample stoppers and blank flask. Both flasks were kept in the dark for 30 min.

For titration, 0.1N $Na_2S_2O_3$ solution was taken in the burettes. Distilled water (100 mL) was added to the sample flask, washing the stopper and shaking well. 1 mL of 1% starch solution was added to the sample flask solution when the solution color changed to lighter during titration. After addition, the flask was shaken well, and titration was resumed. The appearance of the milky white color solution determines the endpoint. The same titration technique was applied to the blank flask.

$$\text{Iodine Value} = \frac{12.69 \times (V_b - V_s) \times N}{N_s}$$

Where,

N_s = Sample weight

V_b = Burette readings for blank titration

V_s = Burette readings for sample flask

N = Normality of sodium thiosulfate solution

Determination of unsaponifiable matter

A.O.C.S. method cd 3-25 was used to determine the saponification value of oil samples [29]. The weight of the clean and dried saponification flask was taken. About 2.5 g of oil was weighed and poured into a flask containing 25 mL of absolute ethanol. The flask was rotated and shaken well, and 1.5 mL KOH solution (3:2 KOH pellets in distilled water) was added to the flask and shaken again. The mixture was refluxed using a condenser until a clear solution was obtained.

$$\text{Unsaponifiable Matter} = \frac{100(A-B)}{Ws}$$

Here,

Ws= weight of sample

A= Residue weight=Flask with residue weight – blank flask weight

B=Weight of fatty acid extracts $=0.282 \times V \times N =$ (g) as oleic acid

N=Normality of Potassium hydroxide solution

Statistical analysis

All statistical analyses were conducted using JMP Pro 17 (SAS Institute). We constructed a linear mixed model utilizing restricted maximum likelihood, incorporating different physiological parameters as continuous variables, while treating the sample as a fixed effect. To evaluate differences between samples, we performed an ANOVA followed by LSMeans Difference Tukey HSD. Probability values <0.05 were considered statistically significant.

Results

Physical Parameters

Three samples were coded as S1, S2 and S3. The physical parameters of oils: color, odor, and visible moisture, were observed and are shown in **Table 2**. All the samples were golden yellow in color, did not have any rancid smell and had no visible moisture.

Table 2: Physical parameters of oil samples as observed through naked eye

Parameters	S1	S2	S3
Color	Golden Yellow	Golden Yellow	Golden Yellow
Odor	No rancid	Not rancid	Not rancid
Visible Moisture	Absent	Absent	Absent

Physiochemical parameters

The physicochemical parameters of the oil samples (**Table 3** and **Figure 2**) did not show any significant differences among the three samples. The moisture content [F (2,6) = 4.5, p = 0.06], acid value [F (2,6) = 0.00, p = 1.00], and free fatty acid content [F (2,6) = 0.33, p = 0.73] of the oil samples were 0.04 to 0.05%, 0.07 mg KOH/g, and 0.03 to 0.04%, respectively. The refractive index [F (2,6) = 2.97, p = 0.13], specific density [F (2,6) = 5.04, p = 0.05], and peroxide value [F (2,6) = 3.54, p = 0.10] were 1.4635 to 1.4679, 0.910 to 0.920 and 2.66 to 2.82 milliequivalents of active oxygen/kg, respectively. The unsaponifiable matter [F (2,6) = 0.72, p = 0.52] and glycerol content [F (2,6) = 1.14, p = 0.38] were 2.1 to 3.3 g/kg and 10.3 to 10.4%, respectively. The iodine value [F (2,6) = 6.00, p = 0.04], saponification value [F (2,6) = 0.72, p = 0.52], and ester value [F (2,6) = 4.5, p = 0.06] were 128 to 140, 189 to 191 and 189 to 191 mg KOH/g, respectively

Table 3. Physiochemical parameters of oils samples as compared to DFTQC standards. The reported values are an average of three replicates and error values denote standard deviations.

Parameters	S1	S2	S3	DFTQC Standards
Moisture content (%)	0.05±0.01	0.06±0	0.04±0.01	Less than 0.1%
Acid value (mg KOH/g)	0.07±0.0	0.07±0.01	0.07±0.0	Less than 0.5
Free fatty acid (%) (Oleic acid)	0.04±0.01	0.03±0.01	0.04±0.01	Less than 0.25
Refractive index	1.4675±0.0006	1.4676±0.0007	1.4635±0.004	1.4660-1.4690
Specific density	0.918±0.007	0.910±0	0.920±0.003	approx. 0.918
Peroxide value (meq of active oxygen/kg)	2.82±0.14	2.66±0.03	2.67±0.03	Less than 10
Unsaponifiable matter (g/kg)	3.3±0.7	2.1±1.0	2.2±0.6	Less than 15
Glycerol (%)	10.4±0.1	10.4±0.2	10.3±0.1	10.26-10.58
Iodine value	128±6	128±4	140±5	110-143
Saponification-value (mg KOH/g)	190±2	191±3	189±1	188-194
Ester value (mgKOH/g)	190±2	191±3	189±1	187.5-193.5

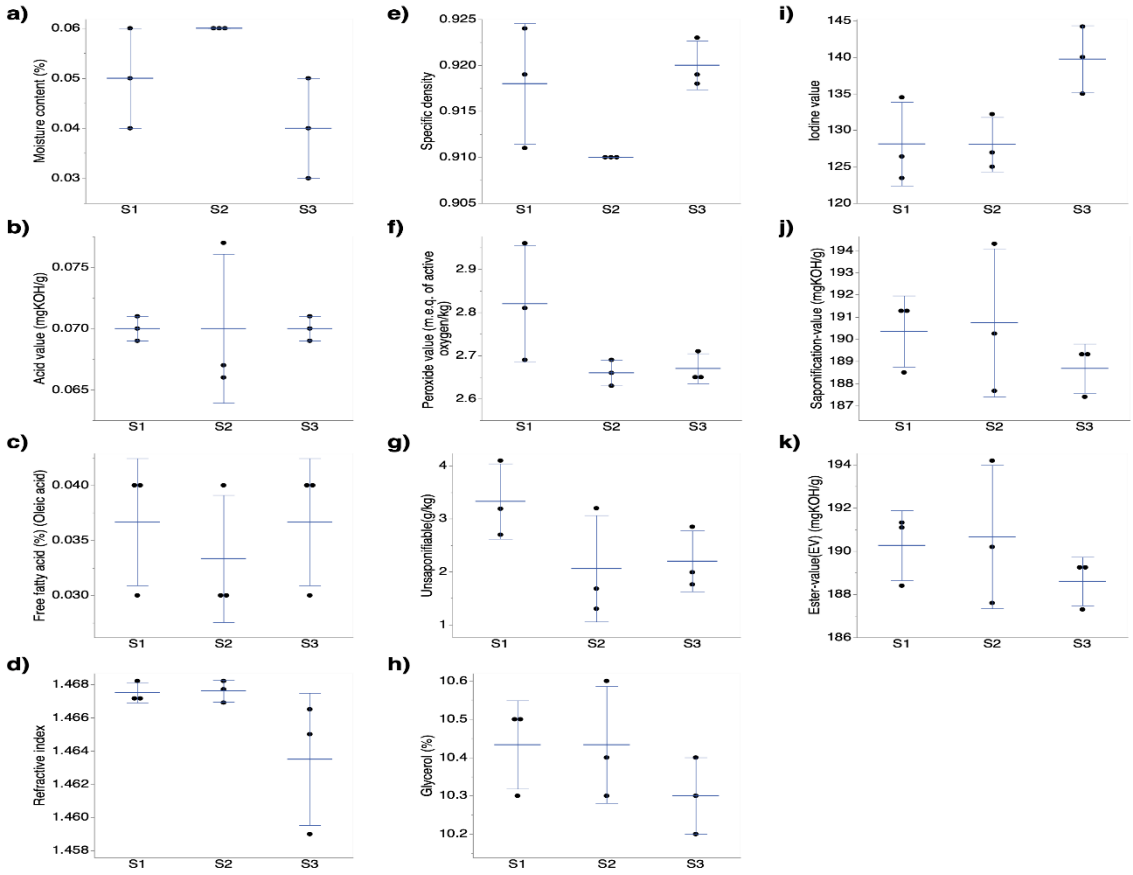

Figure 2. Physiological parameters of three different oil samples. Each horizontal bar represents the mean ±SD for different parameters from **a** to **k**

Discussion

Vegetable oil is vital in food preparation due to its widespread use. Simple lipids, being non-saponifiable, lack fatty acids and are indigestible hydrocarbons. Complex lipids, such as fats and oils, are broken down into smaller units (fatty acids) for absorption and utilization by the body, akin to proteins and carbohydrates. Fatty acids comprise long hydrocarbon chains with a carboxyl group at one end, distinguished by chain length and double bond quantity [30]. Saturated fatty acids have all available bonds filled with hydrogen ions. Additionally, polyunsaturated fats are linked to potentially reduced risk of coronary heart disease.

The primary aim of determining an oil's iodine value was to identify more saturated oil varieties. The results (128 to 140) are within the range of DFTQC standards, indicating all samples meet these guidelines. The iodine value measures the oil's double bond quantity, indicating its susceptibility to oxidation. Oils with iodine content below 100 gI_2/100 g are classified as non-drying oils [31]. The peroxide value of the oil samples (2.66 to 2.82

millequivalents of active oxygen/kg) are within the DFTQC limits (below 10 mill-equivalents of active oxygen/kg oil) [32]. Elevated peroxide values signal increased oxidative rancidity in oils, potentially linked to low or absent antioxidant levels [33].

The refractive index increases with higher fatty acid chain length and unsaturation. The refractive index of the oil samples (1.4635 to 1.4679) is also within the DFTQC standard range (1.4660-1.4690). The DFTQC permits a maximum moisture content of 0.5% in edible oils. The moisture content of the oil samples in this study was 0.04 to 0.05 which is well below the DFTQC standard. Outdated oil manufacturing methods often result in higher moisture levels. Refined oils with increased moisture are prone to rancidity as moisture fosters microbial growth [34].

The specific gravity of oil samples (0.910 to 0.920) was slightly below the WHO limit for sunflower oil (0.919–0.923) [35]. While there's only a slight deviation from norms in specific density, a significant deviation in specific gravity suggests potential issues in manufacturing upgrading and refining procedures. Inadequate refining might result in a higher impurity grade of oil. Specific gravity serves as a marker for oil purity. The acid value reflects the quantity of fatty acids released due to moisture, heat, or lipase action [25]. Rancid edible oil can compromise the nutritional content by degrading vital fatty acids and nutrients, yet immediate adverse health effects are unlikely [15]. The acid value of oil samples (0.07 mg KOH/g) is well within the permissible level (less than 0.5 mg KOH/g) set by DFTQC [30]. Therefore, based on their acid values, the tested oils did not exhibit rancidity.

The saponification value (189 to 191) is well within the permissible range specified by the DFTQC for edible sunflower oil [188-194). Higher saponification values often imply lower impurities [25]. Thus, a higher saponification value typically indicates a higher molecular weight for the fat or oil, suggesting longer or more fatty acid chains. The unsaponifiable matter (2.1 to 3.3 g/kg) is also well below the permissible limit for edibility set by DFTQC (less than 15 g/kg). Overall, the physical and physiochemical parameters of oil samples collected from the market of Pokhara valley are within the range specified by DFTQC for sunflower oil standards.

Conclusion

Factors such as storage conditions, packaging materials, transportation conditions, and chemical composition of oils influence the quality of oils [36]. The results showed that the parameters of the sunflower oil tested were within the permissible range according to the directory of DFTQC (2075). According to the findings, these oils do not pose any health risks to the public. However, consumers should pay attention to storage and transportation conditions, and label information when they choose a product from the market.

Future research should focus on longitudinal studies to monitor changes in oil quality over time and investigate the impact of different processing techniques, such as cold pressing and refining, on oil composition. Studies on the effects of storage conditions, agricultural practices, and climate change on oil quality are also essential. Additionally, optimizing extraction methods, exploring new technologies, and conducting health and nutritional studies will help improve oil production. Economic analyses and market studies can guide producers in adopting best practices and meeting consumer preferences for high-quality oils.

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Conflict of Interest

This work is neither commissioned nor sponsored by any oil manufacturer, distributor, retailer, or regulatory agency. None of the authors have any relationship with the aforementioned entities.

Author Contributions

Ananta Dhakal and Dipak Poudel contributed equally to this work. They designed and performed the experiments, analyzed the results, and prepared the manuscript. Prayan Pokharel assisted with data analysis and manuscript preparation. Santosh Koirala conceptualized the study, designed the experiments, analyzed the data, and prepared the manuscript.

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