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Quality of solid and liquid oils in food applications: Insights from slip melting point and iodine value

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ABSTRACT

This study's main objective was to assess and compare the quality of liquid and solid oil on their iodine value (IV) and slip melting point (SMP). This study employed a comparative experimental design, in which liquid oil (palm olein) and solid oil (a blend of palm olein and palm stearin) were analyzed under controlled laboratory conditions. Standardized analytical methods were used to ensure reliable comparison between oil types. AOCS Official Method Cc 3-25 was used to calculate the SMP, and the Wijs method was used to measure the IV in accordance with AOCS Official Method Cd 1-25. IV solid oil are 51.80, 52.35 and 52.76 $(\sum = 52.30)$, SMP solid oil are 37.4, 37.8 and 37.4 $(\sum = 37.53)$, IV liquid oil are 58.59, 58.55 and 58.11 $(\sum = 58.42)$, SMP liquid oil are 19.6, 19.6 and 19.8 $(\sum = 19.7)$. In conclusion, liquid oil is higher iodine value that means greater content of Unsaturated fatty acids are linked to positive cardiovascular health outcomes. Solid oil, on the other hand, showed a higher slip melting point, which implies greater thermal stability and makes it more appropriate for high-temperature frying applications.

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1. Introduction

Across the world, frying is widely employed in both household cooking and the catering sector to prepare foods with desirable organoleptic properties, such as a crispy texture, appealing aroma, and attractive color (Arslan et al., 2018). Fried food frequently absorbs a significant amount of oil, accounting for up to 50% of their total weight, depending on the frying conditions and oil characteristics (Liu, Tian, Duan, et al., 2021). The physicochemical properties of frying oils play a critical role in determining oil uptake during frying, as well as the texture and quality of the final fried(Liu, Tian, Zhang, et al., 2021). One of the most popular methods of food preparation worldwide is deep-frying, entails submerging food at temperatures between 150 and 190 °C in hot oil. In this process, frying oil functions not only as a heat-transfer medium but also significantly influences the flavor, texture, and overall sensory quality of fried foods (Choe & Min, 2007).

Food consumption is essential for maintaining health, growth, and development; however, the nutritional value of food may be compromised when its quality deteriorates during processing (MacArthur et al., 2021). The most produced and consumed vegetable oil worldwide is palm oil. It makes up over 40% of all vegetable oil traded globally and is produced from the mesocarp of the oil palm fruit

(*Elaeis guineensis*) (Edo et al., 2022). More than three billion people, particularly in Asia, depend on palm oil as a major dietary lipid source (Murphy et al., 2021). Over the past decade, The most produced vegetable oil is now palm oil rather than soybean oil, contributing approximately 57% of global vegetable oil exports (de ALMEIDA et al., 2019).

Lipids represent the most energy-dense macronutrient and act as humans' second main source of nutritional energy. Lipids are crucial for cellular structure in addition to providing energy, metabolic regulation, and signaling pathways, as well as facilitating the absorption and transport of fat-soluble bioactive compounds, including vitamins A, D, E, and K (Altberg et al., 2020). Since palm oil is rich in bioactive chemicals including vitamin E, β-carotene, and palmitic acid, it has long been used for culinary and medical purposes. To broaden its functional applications, crude palm oil (CPO) is commonly separated into solid palm stearin and liquid palm olein, which exhibit contrasting fatty acid compositions and iodine values (Mba et al., 2015). Owing to its favorable quality attributes and functional versatility, palm oil is extensively used worldwide as both a cooking oil and a vegetable shortening (Allam et al., 2023).

Palm oil's liquid component is called palm olein and is widely utilized as a household and commercial frying oil in many countries (Lestari et al., 2024). In contrast, applications like edible coatings and fat-structuring systems, palm stearin is a useful natural hard stock for making trans-free fats. (Subroto & Nurannisa, 2020). Stearin, either used alone or blended with other vegetable oils to form solid oil systems, is extensively applied in frying processes for the production of trans-free snack foods (Serna-Saldivar, 2022). Despite its functional advantages, solid oil is often overlooked, even though it exhibits excellent thermal and oxidative stability, which is increasingly important in meeting global demands for safer processed foods (Ooi et al., 2024).

The SMP is strongly impacted by the oil or fat's triglyceride profile and fatty acid composition. The SMP is typically richer in oils or fats that contain more long triglycerides and saturated fatty acids, making them more likely to be solid at room temperature. On the other hand, because their unsaturated structure prevents the formation of stable solid crystals, SMP is lower in lipids that include a high percentage of unsaturated fatty acids (Zhang et al., 2024).

Additionally, fats and oils contribute significantly to dietary energy intake and improve food digestion (Siswanti et al., 2021). The amount of energy in feed ingredients is strongly influenced by their lipid composition, although oils and fats are often underutilized due to limited technical knowledge (Khaskheli & Chou, 2021). Saturated fats exhibit greater structural stability at high temperatures, making them suitable for specific applications like baking, butter formulations, and frying. However, excessive consumption of diets rich in saturated fatty acids—characterized by low iodine values—has been associated with elevated levels of LDL cholesterol and an increased risk of heart disease, although these effects are influenced by overall dietary patterns (Memon et al., 2024).

By counting the amount of double bonds in fatty acids, the iodine value (IV) is a crucial metric for determining the level of unsaturation in oils and fats. Because iodine reacts with these double bonds, lower IV values indicate fewer unsaturated fatty acids and a relatively higher proportion of saturated fatty acids (Roman-Lara et al., 2025). Frequent eating of fried meals has been linked to an elevated risk of cardiovascular disease, according to epidemiological research, showing a linear dose–response relationship (Qin, Zhang, et al., 2021), and is also linked to a higher prevalence of hypertension and overweight or obesity (Qin, Liu, et al., 2021).

There is a lack of studies that combine Iodine Value (IV) and Smoke Point (SMP) as multidimensional indicators for assessing oxidative stability and correlating these parameters with oil quality degradation during thermal processing and frying. This study is necessary due to its relevance to food safety, given the widespread use of frying as a food processing method and its potential health impacts, They are significantly impacted by the kind of cooking oil utilized. This approach is particularly important in Asia, where frequent consumption of fried foods increases exposure to harmful compounds formed from oil oxidation, posing risks to metabolic and cardiovascular health (Taufik & Atma, 2021). Therefore, applying IV and SMP as selection criteria can support better industrial decision-making and contribute to healthier cooking practices at the consumer level.

2. Method

The samples come from palm oil processing industry in North Sumatra. Liquid oil is derived from palm olein, whereas solid oil is produced by blending palm olein and palm stearin. In accordance with the AOCS Official Method, samples were heated to 60°C in an oven and thoroughly stirred to ensure full melting and homogeneity. The number of replications in this study was determined three times (n = 3) for each sample. This number refers to the standard laboratory analysis practices commonly used in the field of food chemistry, where a minimum of three replications is recommended to obtain representative data (AOAC, 2016).

Slip Melting Point

Slip melting point method based on AOCS Cc 3-25, the sample is tempered at 4 to 10 degrees Celsius for 16 hours after solidifying in an open capillary tube. The tube is then heated in a water bath until the temperature at which the tube's fat column starts to climb (Ahmad Bustamam et al., 2022).

Iodine Value (IV)

This parameter was calculated using the approved AOCS Cd 1–25 procedure. A flask was filled with 0.2 g of oil, 15 ml of carbon tetrachloride solution (CCl_4), and 25 ml of Wijs reagent. 20 milliliters of potassium iodide (KI) aqueous solution (10 g/100 milliliters), 15 milliliters of distilled water, and five drops of 1% starch solution paste were added to the tightly sealed bottle after it had been gently shaken and left in a dark place for an hour. After titrating the solution in the flask with a 0.1 N sodium thiosulfate solution ($Na_2S_2O_3$), the volume V1 of sodium thiosulfate required to turn the solution (make the blue color disappear) from the flask was noted. The volume V0 of sodium thiosulfate used in this titration was noted, and the blank test was also used. Using the following formula, the iodine value (IV) expressed in iodine was determined:

$$\mathbf{IV} = \frac{(\mathbf{V0} - \mathbf{V1})\ \mathbf{x}\ \mathbf{12.69}\ \mathbf{x}\ \mathbf{T}}{\mathbf{M}}$$

Where M (g) is the mass of the test portion, T is the titer of the sodium thiosulfate solution used, V0 (ml) is the volume of the thiosulfate solution for the blank, and V1 (ml) is the volume of the thiosulfate solution for the sample (Houketchang Ndomou et al., 2023).

3. Results and Discussion

The degree of unsaturation of oils and fats is measured by the iodine value using a number of conventional techniques, including the Wijs (Imoisi et al., 2020). Table 1 shows the iodine values and SMP of solid oil and liquid oil. IV solid oil are 51.80, 52.35 and 52.76 ($\sum = 52.30$), SMP solid oil are 37.4, 37.8 and 37.4 ($\sum = 37.53$), IV liquid oil are 58.59, 58.55 and 58.11 ($\sum = 58.42$), SMP liquid oil are 19.6, 19.6 and 19.8 ($\sum = 19.7$). Solid oil has a higher SMP value than liquid oil, but the IV value is lower than liquid oil. A higher IV indicates a greater number of double bonds, which corresponds to a higher proportion of unsaturated fatty acids, especially monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA). These unsaturated fatty acids can be used in place of saturated fats in the diet—which are physiologically necessary—have been linked to better lipid metabolism and cardiovascular health. Because it represents the unsaturation distribution of fatty acids and aids in characterizing the oil's nutritional and functional qualities, IV is still a crucial quality criterion in edible oil analysis (Khaled et al., 2024). The degree of unsaturation influences oil behavior during processing and cooking. Highly unsaturated oils can increase sensory aspects (flavor, texture) in goods when oxidation is controlled and antioxidants are present, regardless of the fact that high temperatures increase their propensity to oxidize. The balance between unsaturation and oxidative stability can be optimized with careful formulation and processing (Abrante-Pascual et al., 2024).

Table 1.
Iodine value (IV) and SMP of Solid Oil (SO) and Liquid Oil (LO)

Sample name	Iodine Value (g I_2/100 g)	SMP (°C)
SO 1	51.80	37.4
SO2	52.35	37.8
SO 3	52.76	37.4
LO 1	58.59	19.6
LO 2	58.55	19.6
LO 3	58.11	19.8

The degree of unsaturation of oils and fats is measured by the iodine value using a number of conventional techniques, including the Wijs (Imoisi et al., 2020). The degree of unsaturation in fats and oils is measured by the iodine value (IV); higher IVs indicate more unsaturated bonds. Evaluating the melting and solidification properties of oil samples—where the temperature of the solidified oil transitions to a fluid state and flows into an open capillary tube—is a common use of the melting point (Roslan et al., 2023)

A higher SMP typically indicates a higher proportion of saturated fatty acids and long-chain triglycerides; conversely, a lower SMP corresponds to an increased percentage of unsaturated fatty acids. Therefore, the SMP provides a physical-chemical indication of whether an oil fraction tends to be solid or liquid at room temperature (Aktas & Ozen, 2021). Comparing between highly unsaturated oils, oils and fractions with greater SMP (more saturated components/solid-fat content) typically show superior oxidative stability at high temperatures, which means a lower rate of degradation product production (e.g., polar compounds, FFAs, peroxides). Consequently, adding greater SMP fractions (such palm stearin) to cooking oil might increase the oil's ability to withstand deterioration over time (Ooi et al., 2024). Low SMP liquid oils, like palm oil, are simple to pour, stay liquid at room temperature, distribute heat well when frying, and often give fried foods a crispy texture and appealing look. However, without stabilization (antioxidants/formulation), these oils are more vulnerable to oxidation because of their increased unsaturated content (Teh et al., 2020). Solid oils/hard fractions (high SMP, e.g. palm stearin): provide thermal and structural stability (useful as hard stocks or for products requiring solid fats). In frying applications, the addition of high SMP fractions can extend the shelf life of the oil and reduce the rate of degradation, but the increased proportion of saturated fats must be considered from a nutritional perspective (Ooi et al., 2024).

Liquid oils with higher IV and lower SMP are more suitable for applications requiring fluidity, rapid heat transfer, and crisp textures, such as shallow frying, chip production, and sautéing. Meanwhile, solid oils with lower IV and higher SMP provide structural stability and greater resistance to thermal degradation, making them better suited for deep-frying operations, bakery shortenings, and formulated fats like margarine. In some applications (e.g., commercial frying or industrial baking), blending both fractions can optimize nutritional value and oxidative stability. Based on the SMP–IV relationship, the most practical recommendation is to use an olein–stearin blend depending on the priority of a health profile (higher IV) or frying stability (higher SMP). Maintaining an IV of 60–80 and an SMP of 26–33°C generally provides an optimal midpoint for performance, safety, and nutritional value.

4. Conclusion

Based on the obtained data, liquid oil exhibits better quality than solid oil due to its higher iodine value (IV) that indicates a greater degree of fat unsaturation. Higher levels of unsaturated fatty acids, especially MUFA and PUFA, are indicated by higher iodine values (IV) in edible oils. In systematic reviews and clinical studies, higher blood lipid profiles have been associated with a diet richer in unsaturated fats and lower in saturated fats, such as lower LDL cholesterol, and a lower risk of cardiovascular disease. It is always advised to swap out saturated fats with oils rich in unsaturated fatty acids in order to promote metabolic and cardiovascular health (Petersen et al., 2024). In some reference, solid oil show better thermal stability and suitable for high-temperature applications including baking, frying, and shortening formulations.

However, SMP and IV should be interpreted in conjunction with other parameters: Solid Fat Content (SFC) provides a more complete temperature–solids content curve and antioxidant content (natural or added) will affect oxidative stability. The combination of these parameters determines an oil's suitability for frying, shelf life, and nutritional implications.

The findings support the formulation of practical recommendations for industry, regulators, and consumers, including IV/SMP-based labeling standards, application-specific oil selection guidelines and classification systems to ensure optimal use of palm-based oils according to thermal processing demands.

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