Research article

Comparative assessment of edible oil oxidative stability through accelerated stability study

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ABSTRACT

Introduction and Aim: The oxidative stability of edible oils is a critical factor influencing their health benefits and suitability for various food applications. The fatty acid composition significantly impacts the susceptibility of oils to oxidation. Edible oils play a pivotal role in cooking and food production, making their oxidative stability a matter of paramount importance. Oxidative stability affects product quality, shelf life, nutritional value, and health benefits. Accelerated oxidative stability tests have emerged to address these challenges more efficiently. Therefore, the objective of the current study was to evaluate the oxidative stability of five edible oils at consistent 90°C: Fish Oil (FO), Coconut Oil (CO), Rice Bran Oil (RBO), Sunflower Oil (SFO) and Palm Oil (PO).

Materials and Methods: Edible oils were procured from the local market. Fish Oil (FO) was acquired from Janatha Aqua products, the oxidative stability of oils was evaluated by using OXITEST apparatus.

Results: The observed results revealed distinct oxidative stability profiles for each oil. CO exhibited the highest stability with an Oxidation Induction Time (OIT) of 136 hours and 38 minutes, highlighting its suitability for high-temperature cooking. PO and RBO showed moderate stability (OIT: 49h 11m and 26h 15m). SFO displayed lower stability (OIT: 10h 9m), while FO was the least stable (OIT: 54m) due to its high unsaturated fatty acid content.

Conclusion: Collectively, the OXITEST provides valuable insights into the oxidative stability of fats and oils, standing out for its real-time, accelerated testing capabilities, and providing faster insights into oxidation behaviour compared to traditional methods.

Keywords: Coconut oil; fish oil; oxidative stability; shelf-life of edible oils.

INTRODUCTION

Edible oils are essential components of diets, serving as cooking mediums and sources of essential fatty acids. The quality and stability of edible oils are critical for maintaining nutritional value, flavor, and safety (1). Structural components of edible oils are triglycerides , which are made up of three fatty acid molecules esterified with glycerol (2). Oil stability and shelf life are mostly determined by fatty acid composition of oil, unsaturated fatty acids are more susceptible to oxidation. The fatty acid composition of edible oils varies widely, and classified as saturated, monounsaturated, and polyunsaturated fatty acids. Unsaturated fatty acids, particularly polyunsaturated are vulnerable to oxidation because it contains multiple double bonds. Unsaturation increases susceptibility to the initiation of oxidation and the subsequent propagation of free radicals (3-5). Monounsaturated fatty acids relatively stable to oxidation, whereas saturated fatty acids are highly stable. Vegetable oils undergo oxidation upon exposure to air, resulting in rancidity called as oxidative rancidity (4). Similarly, moisture (hydrolytic oxidation), light (photooxidation), and heat (thermal oxidation) along with physical state contribute to oil degradation (4,6-10). Among these, oxidative rancidity notably impacts the stability, shelf life, quality, and flavor of vegetable oils (8,11). Vegetable oil oxidation is a chemical reaction between oxygen and unsaturated fatty acids, resulting in the formation of degradation products that can compromise quality, flavor, and nutritional value, potentially contributing to health issues through oxidative stress and inflammation (5,12,13).

Oxidative stability, characterized by resistance to oxidation-induced degradation, is a crucial component in determining the shelf life and suitability of oils for various applications. The process of oxidative degradation is marked by the initiation, propagation, and termination of lipid oxidation (8). Oxidative degradation of oils results in the formation of various products that negatively impact sensory attributes and nutritional quality. Consequently, it is imperative to analyze and ensure the stability of oils to maintain their nutrition and health benefits.The primary oxidative degradation products mainly peroxides and hydroperoxides and secondary products includes ketones, alcohols, aldehydes, free fatty acids, epoxides, ethers, lactones, polymers and other complex compounds, leading to off-flavors, rancidity, and nutritional degradation (11,14-16). These products contribute to oxidative stress and inflammation in the body, potentially leading to conditions such as cancer, cardiovascular diseases, and neurodegenerative disorders (12). Understanding fatty acid composition of each oil is crucial in predicting oxidative degradation and stability (4,17). Monitoring oxidative stability is essential to assess the edible oils ability to resist oxidation and maintain its quality during storage (18). Various techniques were used to evaluate the oxidative stability of oils. These include determining peroxide value, free fatty acid content, p-anisidine value, and Totox value, etc. These indices offer valuable information about the extent of oxidative degradation and the potential for rancidity (7,19). Various methods have been established to analyze oxidative stability, each with its strengths and limitations. The Active Oxygen Method (AOCS, Cd 12b-92) developed by the American Oil Chemists' Society (AOCS) offers valuable insights into oxidative stability; however, is time-consuming. The Oxidative Stability Index (OSI), outlined in ASTM D7545, provides standardized results, but it might not reveal all stages of oxidation. The Schaal Oven Test has historical significance but lacks sensitivity to early oxidation. The Oil Stability Index (AOCS, Cd 12c-16) introduced by AOCS offers a comprehensive approach, but its application requires careful interpretation (4,17,20,21). Additionally, variations in sample composition and conditions can impact the accuracy of results. Moreover, the complexity of certain methods may restrict their application in routine analyses. To overcome this issue, accelerated oxidative stability tests were evolved. The accelerated oxidative stability tests accelerate lipid oxidation by emulating natural storage conditions (16,22-24). These simulations rapidly replicate prolonged oxidation, providing insights into quality, stability, and compositional changes that usually unfold over an extended time frame. Importantly, the Rancimat and Oxitest methods exhibit distinct advantages over these approaches (23).The Rancimat method overcomes the limitations of conventional methods by simulating accelerated oxidation, providing rapid results. However, it might not realistically mimic real-time oxidation conditions. Interestingly, the Oxitest method stands as a promising advancement due to its ability to closely replicate actual oxidation, using pure oxygen to detect early degradation stages. The samples are exposed to high level of oxidative stress in the Oxitest reactor in order to evaluate, in a short period of time. The sensitivity and accuracy overcome the limitation of conventional approaches including rancimat (5,12,13). The comprehensive approach provides valuable insights into the entire oxidation process and is especially advantageous for complex oils and those with varying compositions. Given the importance of oxidative stability in maintaining oil quality and health benefits, the current study aims to investigate the oxidative stability of vegetable oils using Oxitest. The selected oils vary the fatty acid composition such as saturated to unsaturated fatty acid containing edible oils such as CNO, PO, RBO, SFO and FO. The analyzing vegetable oil stability using the Oxitest will provide reliable and accurate results that can correlate with real-time stability, quality and recommendations for optimal storage conditions.

MATERIALS AND METHODS

Materials

CNO, PO, SFO, RBO were procured from local supermarket Mysore, Karnataka, India. FO was acquired from Janatha Aqua products Udupi district Karnataka, India. Vacuum grease obtained from velp® scientifica, Acetone and ethanol solvents purchased from Merck (Mumbai, India) were of analytical reagent grade.

Determination of oxidative stability

Using the OXITEST apparatus (OXITEST, Velp® Scientifica, Usmate, Italy), AOCS method no. Cd 12c-16 was followed. The oxidative stability of oils was evaluated by using OXITEST device which has two thermostated and hermatically sealed titanium chambers capable of holding up to 10 g of sample each. An equal amount (5g) of oil was loaded into each chamber, and Oxygen was purged in both the chambers until the pressure reaches 0 to 8 bar. The OXITEST reactor heated the oil samples between 50 to 110^{0}C and expose them to between 6 to 8 bar of oxygen pressure, which accelerated the oxidative process. The working temperature was set at 90°C, while the initial O_2 pressure was set at 6 bar. The instrument was controlled by OXISoft software monitored the change in pressure and intake of oxygen of the two chambers. Upon test completion, the program automatically computed the Oxidation Induction Time (OIP) from the two-tangent method resultant oxygen curves. This technique calculates the amount of time required to reach the point at which oxidation begins, indicating an abrupt shift in thre rate at which oxygen is used. Three replications of each study resulted in a total of 6 data points being collected for every oil sample.

Statistical analysis

Data analysis were determined using the statistical software SPSS 17.0 (SPSS Inc, Chicago, IL) All the analysis were done in triplicates, and the results are represented as Mean ± SD.

RESULTS

The current study evaluated the oxidative stability of various edible oils, including CNO, PO, RBO, SFO and FO, using the OXITEST instrument as per AOCS method no. Cd 12c-16. The choice of oils was made with a focus on their fatty acid composition, specifically saturated to unsaturated fatty acids ratio. This selection aimed to encompass a broad spectrum of edible oils falling within this range. Oil was loaded into each chamber, and oxygen was purged to maintain pressure between 0 to 6 bar. The oil samples were subjected to accelerated oxidation at 90°C and an initial oxygen pressure of 6 bar. The OXISoft software controlled the instrument, continuously monitoring pressure changes in both chambers to track oxygen uptake by the oil samples. Once oxidation initiated, the pressure dropped, and the software calculated the

Oxidation Induction Time (OIT) using the two-tangent method, representing the time to oxidation initiation. Each analysis was conducted in triplicate, resulting in six data points for each oil sample.

Table 1: Oxidation Induction Time (OIT) for coconut oil, palm oil, sunflower oil, rice bran oil and fish oil.

Sample	Oxidation Induction Time (OIT) at 90°C (h:m)
CO	136:38
PO	49.11
SFO	10:09
RBO	26:15
FO	00:54

The OIT values obtained at 90°C provide a fascinating perspective regarding the edible oils oxidative stability, which is directly related to the amount of double bonds and the fatty acid composition of each oil. Table1 depicts the oxidation Induction Time (OIT) for CNO,PO, RBO, SFO and FO. CNO , well known for having a high level of saturated fats, notably lauric acid (C12:0), exhibited the longest OIT value of 136 hours and 38 minutes (Fig. 1A). The absence of double bonds in saturated fats accounts for their exceptional resistance to oxidation. In contrast, PO, presenting a blend of saturated and unsaturated fatty acids, including C18:1 and C18:2 oleic acid and linoleic acid, displayed a moderate OIT value of 49 hours and 11 minutes, reflecting its mixed stability profile (Fig. 1B). SFO, abundant in polyunsaturated fatty acids like linoleic acid (C18:2) with multiple double bonds, showed relatively lower oxidative stability with an OIT value of 10 hours and 9 minutes (Table 1 and Fig. 1D). RBO, with a balanced composition of fatty acids such as oleic acid (C18:1) and linoleic acid (C18:2), held an intermediate position with an OIT value of 26 hours and 15 minutes, signifying its adaptable nature for diverse culinary applications (Fig. 1C). FO, primarily composed of highly unsaturated omega-3 fatty acids, eicosapentaenoic acid (EPA, C20:5) and docosahexaenoic acid (DHA, C22:6), exhibited the shortest OIT value at 54 minutes (Table 1 and (Fig. 1E), confirming its heightened susceptibility to oxidation at elevated temperatures due to the fatty acid structure and abundance of double bonds. CNO demonstrated the highest stability followed by PO, RBO, SFO and FO. PO showed moderate stability whereas RBO had intermediate stability. Among the tested common cooking oil SFO exhibited relatively lower stability, recording an OIT value of 10 hours and 9 minutes. Interestingly, the FO displayed the lowest stability among the oils, with an OIT value of 54 minutes, ranking as the least stable oil in this study (Fig.2).

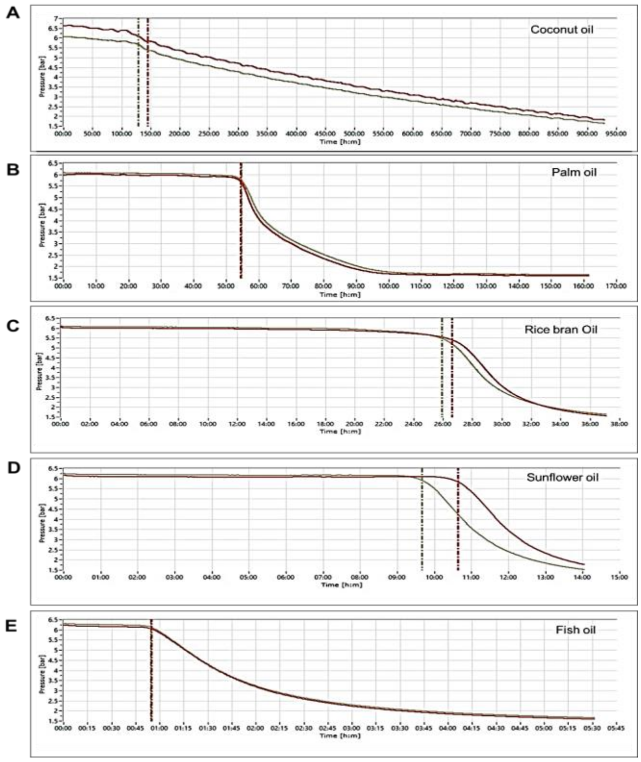

Fig. 1: Evaluation of oxidative stability of the oils. A, Coconut oil; B, Palm oil; C, Rice bran oil; D, Sunflower oil; E, Fish oil. Experiment was repeated three times to acquire data for each oil.

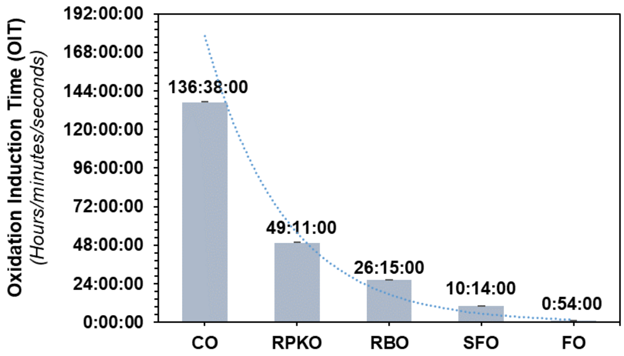

Fig. 2: Oxidative induction period for the initiation of rancidity. Experiment was repeated three times to acquire data for each oil. The data represents the mean ± SD value for each sample. The trend line show the decline pattern of stability, which is due to the fatty acid composition of the oil.

DISCUSSION

These results illuminate the intricate connection between the content of fatty acids, double bond content, and oxidative stability in edible oils, offering valuable guidance for their utilization in specific culinary or industrial contexts (22) reported that the stability of the products due to oxidation was influenced by both the fat type and their composition, highlighting the potential of OXITEST as a valuable and expeditious tool for evaluating oxidative stability.The presence of multiple double bonds makes polyunsaturated fats more prone to oxidation (12,13,5).This ranking provides essential insights into the oils resistance to oxidation, serving as a valuable guide for their selection in various culinary and industrial applications.

Therefore, maintaining the oxidative stability of these oils is crucial to maximize their health benefits while minimizing the potential for adverse effects associated with oxidation (14,15,16). CNO is known for its high stability, having potential health benefits due to the presence of medium chain triglycerides, promoting heart health, aiding weight management, and possessing antimicrobial properties. PO, despite its moderate stability, contains beneficial components like beta-carotene and tocotrienols, offering potential antioxidant and anti-inflammatory effects. Rice bran oil, with its balanced composition, may contribute to lowering cholesterol levels and reducing the risk of cardiovascular diseases. SFO, while lower in stability, is rich in vitamin E and unsaturated fats, potentially promoting skin health and supporting cell function. FO is well known for its anti-inflammatory properties; it is rich in omega-3 fatty acids, benefiting heart and brain health. However, when these oils undergo oxidation, their health benefits can be compromised, leading to adverse effects. Oxidized oils generate harmful compounds such as free radicals, peroxides, and aldehydes, which can trigger oxidative stress and inflammation in the body. Prolonged consumption of oxidized oils has been linked to an higher chance of developing chronic illnesses, including cancer, cardiovascular diseases, and neurodegenerative disorders. Additionally, oxidized oils may develop undesirable flavors, potentially affecting the taste and quality of dishes prepared with them.

CONCLUSION

The oxidative stability of edible oils plays a crucial role in determining their suitability for various applications, including cooking and food production. The fatty acid composition, particularly the presence of double bonds, significantly influences their susceptibility to oxidation. CNO, with its high saturated fatty acid content, exhibited the highest oxidative stability, followed by PO, RBO, SFO, and FO. This ranking provides valuable guidance for selecting oils in different culinary and industrial contexts. The OXITEST instrument proved to be an efficient tool for assessing oxidative stability, offering rapid insights into oil behavior, correlated with their fatty acid compositions. Understanding and monitoring oxidative stability are essential for maintaining oil quality, nutritional value, and health benefits.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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