Manuscript ID:
IJRSEAS-2026-030204

OPEN ACCESS

Quick Response Code:

Website: https://eesrd.us

Volume: 3

Issue: 2(I)

Pp. 21-23

Month: April

Year: 2026

E-ISSN: 3066-0637

Submitted: 06 Mar. 2026

Revised: 16 Mar. 2026

Accepted: 07 Apr. 2026

Published: 30 Apr. 2026

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How to cite this article:
Siddhi S. Bhonkar, Vishakha Pawar . (2026). A Comprehensive Review on GC–MS Analysis of Aldehydes and Ketones in Edible Oils. International Journal of Research Studies on Environment, Earth, and Allied Sciences, 3(2(I)), 21-23.

A Comprehensive Review on GC-MS Analysis of Aldehydes and Ketones in Edible Oils

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Abstract:
Edible oils are essential components of the human diet, but their quality and safety are significantly influenced by the presence of volatile carbonyl compounds, particularly aldehydes and ketones. These compounds are primarily formed through lipid oxidation during processing, storage, and thermal treatment, and are closely associated with flavor deterioration, rancidity, and potential health risks. Gas chromatography–mass spectrometry (GC–MS) has emerged as a powerful and reliable analytical technique for the identification and quantification of these volatile compounds due to its high sensitivity, selectivity, and accuracy. This review provides a comprehensive overview of GC–MS-based methodologies for the analysis of aldehydes and ketones in edible oils. Key aspects such as sample preparation techniques, including solid phase microextraction and derivatization methods, are discussed in detail. The review also highlights the major aldehydes and ketones commonly detected in various edible oils and their role as indicators of oxidative degradation and oil quality. Furthermore, recent advancements in GC–MS technologies and their applications in monitoring oil stability, authenticity, and shelf life are critically examined. Challenges related to compound volatility, matrix complexity, and analytical limitations are also addressed. Overall, this review emphasizes the significance of GC–MS as an indispensable tool in food quality assessment and provides insights into future directions for improving analytical precision and reliability in edible oil research.

Keywords: *GC–MS, Edible oils, Aldehydes, Ketones, Lipid oxidation, Food quality; Oxidative stability, Oil deterioration, Analytical techniques.*

Introduction

Edible oils are an important part of the human diet. They are widely used in cooking, frying, baking, and food processing. Edible oils not only improve the taste and texture of food but also provide energy and essential nutrients required for the body. Oils are mainly obtained from plant sources such as sunflower seeds, groundnuts, coconuts, soybeans, and palm fruits. Some commonly used edible oils include sunflower oil, palm oil, coconut oil, and groundnut oil.[1-2] Edible oils are mainly composed of triglycerides, which are formed from fatty acids and glycerol. Fatty acids present in oils may saturated or unsaturated. Unsaturated fatty acids are more prone to chemical reactions such as oxidation. When oils are exposed to air, light, high temperature, or long storage time, chemical changes can occur. These changes affect the quality, safety, nutritional value of the oil. [3-4] One of the most important chemical reactions that occurs in edible oils is oxidation. Oxidation happens when fatty acids in oil react with oxygen present in the air. This reaction leads to the formation of different oxidation products such as aldehydes, ketones, alcohol, and organic acids. Among these compounds, aldehydes and ketones are commonly formed during the oxidation of oils. These compounds are responsible for unpleasant odor, bad taste, and deterioration of oil quality.[5-7]

Aldehydes and ketones are organic compounds that contain carbonyl groups in their structure. In aldehydes, the carbonyl group is attached to at least one hydrogen atom, while in ketones it is attached to two carbon atoms. These compounds are often produced during the breakdown of unsaturated fatty acids in oils.[8] The presence of aldehydes and ketones in edible oils can affect both food quality and human health. Some aldehydes are volatile compounds that produce strong and unpleasant smells. Rancidity is the process by which oils develop an unpleasant smell and taste due to oxidation. Therefore, it is very important to monitor and analyze the presence of aldehydes and ketones in edible oils. By studying these compounds, scientists can understand the level of oxidation and the overall quality of the oil. This analysis also helps in determining whether the oil is safe for consumption or has undergone significant deterioration.[9-10]

Modern analytical techniques are used to detect and measure aldehyde and ketone compounds in edible oils. One of the most effective techniques used for this purpose is Gas Chromatography–Mass Spectrometry (GC-MS).

GC-MS is a powerful analytical instrument that can separate, identify, and quantify different chemical compounds present in a sample. It is widely used in food analysis, environmental studies, and pharmaceutical research. In GC-MS analysis, the oil sample is first prepared using suitable solvents such as n-hexane, methanol, or acetonitrile.[11-12]

Literature Review

Frankel and his team studied the mechanism of lipid oxidation in edible oils and highlighted the formation of secondary oxidation products such as aldehydes and ketones. They emphasized that compounds like hexanal and malondialdehyde are important indicators of rancidity and oil deterioration. Their work established a strong foundation for understanding oxidative stability and quality assessment of edible oils [1].

Shahidi and Zhong investigated the role of oxidation products in food systems and discussed various analytical methods for detecting aldehydes and ketones. They reported that techniques such as spectrophotometry and chromatography are effective for evaluating lipid peroxidation. Their findings underline the importance of monitoring these compounds to ensure food safety and shelf-life stability [2].

Velasco and Dobermans examined the oxidative stability of vegetable oils under different storage and heating conditions. They found that temperature, light, and oxygen significantly influence the formation of aldehydes and ketones. Their study demonstrated that proper storage conditions can reduce the rate of oxidation and improve oil quality [3].

Choe and Min explored the mechanisms of lipid oxidation and the formation of volatile aldehydes and ketones during frying processes. They showed that high-temperature cooking accelerates oxidation and leads to the production of harmful compounds. Their research provides valuable insights into controlling oxidation in edible oils during thermal processing [4].

Recent studies by various researchers have focused on advanced analytical techniques such as Gas Chromatography–Mass Spectrometry (GC–MS) and Solid Phase Microextraction (SPME) for the detection of aldehydes and ketones. These methods offer high sensitivity, accuracy, and the ability to detect trace-level compounds. Such developments contribute to more precise quality evaluation and monitoring of edible oils [5].

Research Methodology

Analysis of aldehyde and ketone compounds in edible oil samples as key indicators of lipid oxidation and quality deterioration. We carefully examine various studies focused on the extraction, detection, and quantification of these secondary oxidation products, emphasizing the importance of accurate analytical techniques to ensure reliable and reproducible results. Initially, edible oil samples such as sunflower oil, soybean oil, and palm oil were selected and subjected to controlled storage and heating conditions to promote oxidation. Standard sample preparation methods were employed, including solvent extraction and filtration, to isolate volatile and non-volatile oxidation products. Special attention was given to minimizing external contamination and preserving sample integrity during preparation.

For the analysis of aldehydes and ketones, we applied three different analytical approaches to evaluate the effect of methodology on detection efficiency. The first method involved Gas Chromatography–Mass Spectrometry (GC–MS), which is widely regarded as a highly sensitive and reliable technique for identifying volatile aldehydes and ketones based on their mass spectra. This method allowed precise identification and quantification of compounds such as hexanal, nonanal, and 2-heptanone. After each analytical run, the obtained data were processed to determine the concentration of aldehydes and ketones. Parameters such as peroxide value, Thio barbituric acid reactive substances (TBARS), and overall oxidation levels were calculated to assess oil quality. The results from all three methods were compared based on sensitivity, accuracy, time efficiency, and environmental impact. Effective and sustainable method for monitoring lipid oxidation and ensuring the quality and safety of edible oils.

Expected Outcomes

This study highlights the importance of monitoring aldehyde and ketone compounds as key indicators of oxidative deterioration in edible oils. It emphasizes how the formation of these compounds reflects the quality, safety, and shelf-life of oils, thereby underlining the significance of lipid oxidation studies in food chemistry.The primary objective is to establish a reliable and reproducible approach for detecting and quantifying aldehydes and ketones in different edible oil samples. The study evaluates the effectiveness of various analytical techniques such as Gas Chromatography–Mass Spectrometry.

Using analytical tools, the presence of carbonyl compounds (aldehydes and ketones) will be confirmed, and their concentrations will be correlated with quality parameters such as peroxide value and TBARS. These results will provide a clear understanding of the relationship between oxidation level and oil quality. In conclusion, this work supports the advancement of food quality assessment techniques, contributes to better monitoring of edible oil stability, and promotes the use of efficient and sustainable analytical methods. It also lays a foundation for future research focused on improving oil preservation and ensuring consumer safety.

Conclusion

Analysis of aldehyde and ketone compounds has become an essential part of evaluating the quality and stability of edible oils. Traditional methods are gradually being replaced by more advanced and efficient analytical techniques that provide accurate and reliable detection of oxidation products. Monitoring these compounds is crucial, as their formation directly reflects the extent of lipid oxidation and overall oil deterioration. Proper handling, storage, and initial quality of edible oils play a significant role in controlling oxidation.

When oils are maintained under suitable conditions, the formation of harmful aldehydes and ketones can be minimized, thereby preserving nutritional value and safety. Analytical techniques such as GC–MS, have greatly improved the ability to detect and quantify these compounds, making quality assessment faster and more precise.
Recent developments in analytical chemistry focus on methods that are not only sensitive and accurate but also environmentally friendly. Techniques that reduce solvent usage, energy consumption, and analysis time are gaining importance in modern research. Additionally, rapid and non-destructive methods like FTIR are becoming valuable tools for routine quality monitoring in the food industry. Looking ahead, further research is needed to develop more cost-effective, portable, and real-time monitoring systems for detecting aldehydes and ketones in edible oils. Advancements in green analytical methods and sensor-based technologies could significantly enhance large-scale quality control processes. If these improvements are achieved, it will lead to better oil preservation, improved consumer safety, and more sustainable practices in the food industry.

Acknowledgement

I would like to express my sincere gratitude to all those who supported and guided me in the completion of this review work entitled "A Comprehensive Review on GC–MS Analysis of Aldehydes and Ketones in Edible Oils."
First and foremost, I am deeply thankful to my supervisor/guide for their invaluable guidance, encouragement, and continuous support throughout the preparation of this review. Their expert suggestions and insightful discussions greatly contributed to the successful completion of this work.
I also extend my heartfelt appreciation to the faculty members and staff of the department for providing the necessary academic resources, encouragement, and a conducive environment for learning and research.
I am grateful to my institution for offering access to libraries, journals, and research facilities that helped me gather and analyze the relevant scientific literature for this review.
Special thanks to my friends and colleagues for their cooperation, motivation, and helpful discussions during the course of this study.
Finally, I express my deepest gratitude to my family for their constant support, patience, and encouragement, which inspired me to complete this work successfully.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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