

## Toxicology of oils and fats: Understanding health implications and safety measures

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### Abstract

This review delves into the toxicology of edible oils and fats, focusing on their health implications, processing methods, contaminants, and safety practices. It discusses the types of fats, processing techniques, contaminants, health effects, safe consumption practices, current research, and future directions. The review distinguishes between saturated, unsaturated, and trans fats, examines harmful contaminants, and provides guidelines for healthier choices. It also highlights the impact of dietary fat choices on health and identifies potential future research areas such as personalized nutrition and sustainable fat sources. The review aims to provide practical recommendations for improving health and safety.

**Keywords:** Toxicology; Contaminants; Saturated Fats; Omega-3 Fatty Acids; Edible Safety

### 1. Introduction

Edible oils and fats are essential components of the human diet, providing energy, essential fatty acids, and aiding in the absorption of fat-soluble vitamins [1–4]. They are sourced from various origins:

**Animal sources:** Animal sources of edible oils and fats include butter, lard, tallow, meat and dairy products, and chicken fat [5]. Butter, which is high in saturated fats and cholesterol, should be used sparingly due to its potential to increase LDL cholesterol levels and risk of heart disease. Lard, obtained from pork fat, is a solid fat commonly used in cooking and baking. Tallow, made from beef or lamb fat, is similarly high in saturated fats and carries comparable health risks. Meat and dairy products, such as cheese and cream, also contribute to a high fat intake. Excessive consumption of animal fats can negatively affect heart health. To mitigate these risks, moderation is essential, and incorporating healthier options like plant-based oils can help lower saturated fat consumption.

**Plant sources:** Plant-based edible oils and fats offer healthier alternatives to animal fats by providing beneficial unsaturated fats. Oils such as olive, canola, avocado, coconut, and palm, as well as those from nuts and seeds, are rich in monounsaturated fats and antioxidants. These oils are commonly used in cooking, baking, and as salad dressings. Monounsaturated fats in olive, canola, and avocado oils can help reduce LDL cholesterol levels and lower the risk of heart disease. Meanwhile, the polyunsaturated fats found in nut and seed oils support heart health and help reduce inflammation. However, oils high in saturated fats, like coconut and palm oil, can affect heart health if consumed in excess. A well-balanced diet that includes plant-based oils can provide essential nutrients and contribute to overall well-being.

**Processed sources:** Processed sources of edible oils and fats are derived from raw materials through industrial methods, often including modified or refined oils used in cooking, baking, and edible manufacturing. Key examples include

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margarine, shortening, vegetable oil blends, fried edibles oils, and creamers. These oils can have health implications, including trans fats, saturated fats, and oxidation. Trans fats can raise LDL cholesterol levels and lower HDL cholesterol, increasing the risk of heart disease. Saturated fats can contribute to elevated cholesterol levels and cardiovascular issues when consumed in excess. Refinement can remove beneficial nutrients, leading to harmful compounds. To minimize health risks, limit consumption of processed oils and fats, opt for oils with minimal processing, and avoid products with high trans fat content.

Fats can be categorized into saturated, unsaturated, and trans fats. Understanding the composition and effects of these fats is crucial for assessing their impact on health. Toxicology is vital for evaluating the safety and health risks associated with edible oils and fats. Health implications include cardiovascular diseases, cancer, obesity, metabolic disorders, and liver health. Contaminants in oils include polycyclic aromatic hydrocarbons (PAHs), 3-MCPD, glycidyl esters, and pesticides. Understanding the toxicology of edible oils and fats helps consumers make informed dietary choices, informs regulatory bodies, and supports public health initiatives.

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## 2. Methodology

This review examines the toxicological effects of oils and fats on human health, addressing potential risks, mechanisms of toxicity, and safety measures. The aim is to consolidate current research on the toxicology of oils and fats, identify associated health risks, assess safety measures, and pinpoint knowledge gaps for future investigation. The review utilizes academic databases such as PubMed, Google Scholar, JSTOR, Scopus, and Web of Science, incorporating peer-reviewed articles, reviews, and clinical studies published in the last 20 years (2004-2024) in English, focusing on human health. Information is categorized into themes including types of oils and fats, mechanisms of toxicity, health implications, and safety measures and regulations.

The review discusses the topic's importance, explains the literature search process, and details the main findings. It covers themes such as types of oils and fats, mechanisms of toxicity, health implications, safety measures and regulations, and the evaluation of regulatory policies. The review concludes by summarizing the main findings, discussing public health implications, and offering suggestions for future research directions. Additionally, it includes a comprehensive list of all referenced studies and sources.

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## 3. Results and discussion

### 3.1. Types of fats and their Sources

This chapter discusses different types of fats and their sources [6–13].

#### 3.1.1. Saturated fats

Saturated fats are found in both animal and plant sources and are characterized by having no double bonds between carbon atoms. They are present in red meat, poultry, dairy products, and processed meats. Consuming high amounts of saturated fats can raise LDL cholesterol levels, which may lead to cardiovascular diseases and weight gain. Health organizations recommend limiting saturated fat intake to less than 10% of daily calories. To achieve this, one should reduce the consumption of edibles high in saturated fats and choose healthier fat sources, such as unsaturated fats found in plant-based oils. Balancing saturated fat intake with unsaturated fats can contribute to maintaining heart health and overall well-being.

#### 3.1.2. Monounsaturated fats

Monounsaturated fats, which have one double bond in their fatty acid chains, are a type of unsaturated fat with notable health benefits. They are found in olive oil, avocado oil, canola oil, nuts and seeds, and nut butters. These fats can help lower LDL cholesterol levels, reduce inflammation, and aid in weight management. However, because they are calorie-dense, they should be consumed in moderation. Using healthy substitutes, such as olive oil, can improve heart health. Including monounsaturated fats in a balanced diet contributes to better overall nutrition and supports long-term health.

#### 3.1.3. Polyunsaturated fats

Polyunsaturated fats, found in various plant and animal sources, are essential for health and offer several benefits. They are primarily present in omega-3 fatty acids, which are found in fatty fish, flaxseeds, chia seeds, and walnuts. These fatty acids are also found in vegetable oils, nuts, and seeds. Algal oil serves as a plant-based source of omega-3s.

Polyunsaturated fats can help lower LDL cholesterol levels, reduce inflammation, and support brain function. However, since they are calorie-dense, they should be consumed in moderation. Incorporating polyunsaturated fats into a balanced diet can provide essential nutrients and support overall health. In summary, polyunsaturated fats are a crucial component of a healthy diet, offering benefits for heart health, inflammation, and brain function.

#### *3.1.4. Trans fats*

Trans fats are unsaturated fats that have been chemically altered through hydrogenation, resulting in two types: industrially produced trans fats and naturally occurring trans fats. Industrially produced trans fats are found in partially hydrogenated oils used in processed edibles, while naturally occurring trans fats are present in small amounts in some animal products. Trans fats have significant health implications, including increasing LDL cholesterol levels and decreasing HDL cholesterol levels, which can raise the risk of cardiovascular diseases. They can also promote inflammation, potentially leading to chronic conditions such as diabetes. Additionally, a high intake of trans fats can contribute to weight gain and obesity, increasing the risk of metabolic syndrome. Regulatory measures and dietary guidelines stress the importance of reducing or eliminating trans fat intake to enhance overall health and well-being.

### **3.2. Processing of oils and fats**

Edible oil and fat production involves three key processing techniques: hydrogenation, refining, and mechanical extraction [14–18]. Hydrogenation creates stable fats, but can produce trans fats, leading to health risks. Refining purifies crude oils but can strip nutrients and leave trace chemicals. Mechanical extraction methods, like cold pressing and expeller pressing, use physical processes but may be less efficient and costly. Understanding these processes helps consumers and producers make informed choices about oil consumption.

#### *3.2.1. Hydrogenation*

Hydrogenation is a chemical process that converts unsaturated fats into saturated fats by adding hydrogen atoms to their fatty acid chains. This process results in a more stable and solid product at room temperature. Hydrogenated oils are commonly used in the edible industry to improve texture and extend shelf life and are also used in non-edible products like cosmetics and soaps. However, partial hydrogenation can produce trans fats, which are associated with adverse health effects, such as increased LDL cholesterol levels and a higher risk of cardiovascular disease. Regulatory measures have been implemented to limit or ban partially hydrogenated oils, and edible labels often indicate their presence. To avoid these negative effects, alternatives like non-hydrogenated plant oils, such as olive oil and canola oil, are recommended.

#### *3.2.2. Refining*

It is a process that purifies crude oils and fats by removing impurities and unwanted components. It involves several steps, including degumming, neutralization, bleaching, deodorization, and winterization. Refined oils are used in various applications such as the edible industry, cosmetics, pharmaceuticals, and biodiesel production. However, refining can decrease the nutritional value of oils by removing beneficial compounds like tocopherols and phytosterols. Additionally, some refining processes may leave trace amounts of chemicals, which could pose potential health risks if not properly removed. Regulations and quality standards ensure that refined oils meet safety and purity criteria, and edible labels indicate whether the oil has been refined. Alternatives like cold-pressed or unrefined oils retain higher nutritional value but may have lower smoke points and shorter shelf lives. Understanding the refining process helps consumers make informed decisions about oil consumption and its health implications.

#### *3.2.3. Mechanical extraction methods*

These techniques used to obtain oils and fats from plant and animal sources without the use of chemical solvents. These methods rely on physical processes to separate the oil from the raw materials, producing high-quality, minimally processed oils. Key methods include:

**Cold pressing:** Involves grinding raw materials and pressing them at low temperatures to extract oil, which helps preserve the oil's natural nutrients and flavor. **Expeller pressing:** More efficient and capable of handling larger quantities of material, though it generates some heat due to friction. **Hydraulic pressing:** Uses a hydraulic press to extract oil from materials with lower oil content, applying high pressure to facilitate extraction. **Solvent-free methods:** Include cold and expeller pressing, which do not use solvents like hexane, ensuring the oil remains free from chemical residues. **Enzymatic extraction:** Utilizes specific enzymes to break down cell walls and release the oil, enhancing extraction efficiency and oil quality. However, mechanical methods can be less efficient and more costly due to the need for specialized equipment and labor.

### 3.3. Contaminants in edible oils and fats

Edible oils and fats pose significant health risks due to contamination with harmful substances during production, processing, and storage. Polycyclic Aromatic Hydrocarbons (PAHs), 3-MCPD and glycidyl esters, and pesticide residues are particularly concerning. PAHs, formed during incomplete combustion, can enter the food chain through cooking methods and environmental contamination. 3-MCPD and glycidyl esters are carcinogens that can cause kidney damage and reproductive toxicity. Pesticide residues, used in agriculture, can cause endocrine disruption and neurotoxicity. Understanding and managing these contaminants is crucial for public health and safe food production [19–23]. Contaminants in edible oils and fats can pose significant health risks.

#### 3.3.1. Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds formed during the incomplete combustion of organic materials, such as fossil fuels, tobacco smoke, and edibles. These persistent environmental pollutants are commonly found in edible products, particularly in oils and fats subjected to high-temperature processing. PAHs can enter edibles through various routes, including cooking methods, environmental contamination, and exposure to contaminated soil, air, and water. Exposure to PAHs poses health risks, including increased cancer risk, genetic mutations, and respiratory issues. To mitigate these risks, regulations and safety measures focus on regularly assessing PAH levels in edible products, employing mitigation strategies like using lower cooking temperatures and avoiding charring, ensuring proper storage of oils and fats to minimize contamination, and conducting routine tests to ensure compliance with safety standards.

#### 3.3.2. 3-MCPD and glycidyl esters

3-MCPD (3-monochloropropane-1,2-diol) and glycidyl esters are chemical contaminants that can form during the processing of edible oils and fats, particularly under high-temperature conditions. 3-MCPD is produced when hydrochloric acid reacts with glycerol during the refining process, especially in deodorization, and is classified as a probable human carcinogen that may cause kidney damage and reproductive toxicity. Glycidyl esters result from the reaction between glycidol and fatty acids during high-temperature processing and are considered potential carcinogens with possible genotoxic effects.

Both 3-MCPD and glycidyl esters can enter edible products through high-temperature refining methods like deodorization and bleaching. Although less common, environmental sources may also contribute to their presence.

The health implications of these contaminants include increased cancer risk. Long-term exposure to 3-MCPD may lead to kidney damage and reproductive issues, while glycidyl esters are linked to potential genotoxic effects.

Regulatory agencies set limits on the levels of 3-MCPD and glycidyl esters in edible products to protect consumer health. Mitigation strategies involve optimizing processing conditions to reduce the formation of these contaminants and using alternative methods to avoid their creation. Regular testing and adherence to safety regulations are essential for ensuring that edible products meet safety standards and are free from excessive contaminants.

To ensure consumer safety, it is advisable to choose oils and fats processed with methods that minimize 3-MCPD and glycidyl ester formation. Ongoing testing and compliance with safety regulations are crucial for reducing exposure to these harmful substances and ensuring overall consumer safety.

#### 3.3.3. Pesticide residues

These materials are trace amounts of chemicals used in agriculture to control pests, weeds, and diseases. They can be found in oils and fats from crops treated with pesticides. Long-term exposure to pesticide residues can lead to health issues, including endocrine disruption, neurotoxicity, and potential carcinogenic effects. Regulatory limits and good agricultural practices (GAP) help minimize residue levels. Thorough washing and processing of agricultural products can reduce residues. Edible safety recommendations include choosing organic products, regular testing, and being informed about pesticide use. Proper agricultural practices, regulatory oversight, and consumer awareness are crucial for reducing exposure and maintaining edible safety.

#### 3.3.4. Other contaminants

These contaminants include heavy metals, phthalates, mycotoxins, and microbial agents. Heavy metals such as lead, cadmium, arsenic, and mercury can accumulate in soil and water, subsequently contaminating crops and edible

products [24-26]. Phthalates, used in plastics, can leach into edibles through packaging materials and processing equipment, potentially leading to reproductive toxicity and developmental issues. Mycotoxins, produced by fungi, pose risks of acute poisoning, liver damage, and cancer. Additionally, microbial contaminants like bacteria, yeast, and molds can cause foodborne illnesses and spoilage.

To mitigate these risks, regulatory standards, quality assurance practices, and Good Manufacturing Practices (GMP) are crucial. Ensuring proper storage, handling, and regular monitoring is essential for maintaining edible safety and minimizing contamination.

### **3.4. Health effects of fats**

Cardiovascular disease (CVD) is a major public health concern, influenced by dietary choices and fat intake. Saturated fats, found in animal products and processed foods, increase heart disease risk. Unsaturated fats, found in plant-based oils and nuts, protect heart health. Trans fats, resulting from industrial processing, exacerbate cardiovascular risk. Understanding these interactions is crucial for managing and preventing CVD, promoting a balanced diet and making informed food choices [5,19,27–33].

#### *3.4.1. Cardiovascular disease (CVD) and dietary fats*

Cardiovascular disease (CVD) is a serious health issue affecting the heart and blood vessels, influenced significantly by diet, particularly fat intake. High saturated fat intake, found in red meat, poultry, dairy products, and processed meats, increases cholesterol levels and the risk of heart disease. Health organizations recommend limiting saturated fat intake to less than 10% of daily calories. Unsaturated fats, such as those in olive oil, avocados, and nuts, can improve heart health. Trans fats, found in industrially produced and naturally occurring forms, increase the risk of cardiovascular diseases and inflammation. A balanced diet rich in fruits, vegetables, whole grains, and lean proteins is recommended.

#### *3.4.2. Types of fats and their health implications*

Fats significantly impact health. Cardiovascular disease (CVD) refers to a range of conditions affecting the heart and blood vessels, including coronary artery disease, heart attacks, strokes, and hypertension. Diet, particularly fat intake, plays a crucial role in both the development and management of CVD. Saturated fats, present in red meat, poultry, dairy products, and processed meats, can lead to elevated cholesterol levels and an increased risk of cardiovascular disease. High intake of saturated fats contributes to the development of atherosclerosis and heart disease. Health organizations recommend limiting saturated fat intake to less than 10% of daily calories. Instead, opting for unsaturated fats, such as those found in olive oil, avocados, and nuts, can enhance heart health and help maintain healthier cholesterol levels. Moderation in saturated fat consumption is essential for overall well-being.

#### *3.4.3. The risks of trans fats*

Trans fats, a type of unsaturated fat, are chemically altered through hydrogenation and can be found in both industrially produced and naturally occurring forms. They are associated with an increased risk of cardiovascular diseases, promotion of inflammation, and contribution to weight gain. Health organizations recommend reducing or eliminating trans fats from the diet, particularly industrially produced ones. Opting for healthier alternatives, such as plant-based oils, nuts, and seeds, supports better heart health. Being mindful of edible labels can help manage trans fat consumption effectively.

#### *3.4.4. The benefits of monounsaturated and polyunsaturated fats*

Monounsaturated fats, present in olive oil, avocado oil, canola oil, nuts, seeds, and animal products like chicken and turkey, provide several health benefits, including improved cholesterol levels, reduced inflammation, and support for weight management. These fats should be consumed in moderation as part of a balanced diet and can serve as healthy alternatives to saturated fats. For a better dietary fat profile, choose sources such as olive oil, nuts, and avocados.

#### *3.4.5. Comprehensive dietary recommendations*

To support cardiovascular health and manage the risk of cardiovascular disease (CVD), emphasize a balanced diet rich in fruits, vegetables, whole grains, and lean proteins. To reduce the risk of cancers such as breast and colorectal, limit intake of saturated fats and avoid trans fats, which are linked to increased risks of prostate and colorectal cancers; incorporate polyunsaturated fats for potential protective benefits against certain types of cancer. To prevent obesity and metabolic syndrome, reduce consumption of saturated and trans fats and opt for healthier fats such as monounsaturated (MUFAs) and polyunsaturated fats (PUFAs) to maintain a healthy weight and improve metabolic

health. To support liver health and prevent non-alcoholic fatty liver disease (NAFLD), limit excessive intake of unhealthy fats and include healthy fats and omega-3 fatty acids in your diet.

#### *3.4.6. Safe consumption practices*

To ensure the safe consumption of edible oils and fats, several best practices should be followed. Opt for baking and roasting instead of frying to reduce the formation of harmful compounds like acrylamides and PAHs, and avoid excessively high cooking temperatures by choosing oils with high smoke points to prevent degradation [34–43]. Select high-quality oils with a favorable fatty acid profile and avoid partially hydrogenated oils that contain trans fats; instead, choose oils rich in monounsaturated and polyunsaturated fats, such as olive oil, avocado oil, and canola oil. Store oils away from heat, light, and moisture to prevent oxidation and spoilage, using them while fresh and in appropriate containers. Regularly clean cooking equipment to remove residual fats or contaminants that could affect safety. Pay attention to edible labels to understand fat content and avoid products with high levels of saturated and trans fats, opting for those with healthier fat profiles and lower harmful compound levels. Use non-toxic cookware to prevent leaching of harmful substances and ensure that cooking practices adhere to safety guidelines to minimize health risks. By following these practices, consumers can reduce harmful compound formation, maintain the quality of oils and fats, and promote healthier cooking methods.

#### *3.4.7. Understanding edible labels*

Edible labels offer crucial details about a product's nutritional profile, including the types and quantities of fats present. They indicate total fat, saturated fat, trans fat, and occasionally specific unsaturated fats. By interpreting these labels, consumers can make better choices, such as selecting items with lower saturated and trans fats and higher amounts of healthier fats like monounsaturated and polyunsaturated fats. Additionally, edible labels usually provide information on calories, vitamins, and other nutrients, aiding in overall dietary management and health.

#### *3.4.8. Healthy cooking practices*

To minimize harmful compounds in edible oils and fats, consider opting for baking and roasting rather than frying to reduce acrylamides and PAHs. Avoid cooking at high temperatures and use oils with high smoke points. Select high-quality oils with a favorable fatty acid profile, steering clear of partially hydrogenated oils. Store oils away from heat and light, use them while fresh, and choose non-toxic cookware. Regularly clean cooking equipment to eliminate residual fats or contaminants. Implementing these practices will help promote healthier cooking and reduce the formation of harmful compounds in edible oils and fats.

### **3.5. Current research and developments**

The edible oils and fats industry is constantly evolving due to advancements in processing techniques, fatty acid research, and regulatory measures. Techniques like cold pressing, expeller pressing, and supercritical fluid extraction enhance oil quality and nutritional benefits. Green processing technologies address environmental concerns. Regulatory measures ensure safety, quality, and consumer education, promoting healthier oils and improved public health [44–51].

#### *3.5.1. Advances in processing techniques*

Current research focuses on advances in processing techniques that enhance health outcomes and minimize harmful compounds. Key developments include cold pressing and expeller pressing, which preserve oil quality and nutrients; supercritical fluid extraction for purer oils; high-pressure processing to maintain nutritional quality and extend shelf life; advanced filtration methods for better purity and safety; enzyme technology for more efficient extraction; nanotechnology for improved stability and delivery of beneficial compounds; and green processing technologies to reduce environmental impact. These innovations collectively contribute to producing healthier oils with fewer contaminants, improved flavor profiles, and enhanced nutritional benefits.

#### *3.5.2. New findings on fatty acids*

New findings on fatty acids highlight the health benefits of omega-3 fatty acids, which can reduce inflammation, improve heart health, and support cognitive function. Maintaining a balanced omega-6 to omega-3 ratio is crucial for reducing inflammation and promoting overall health. Monounsaturated fats, found in olive oil, avocados, and nuts, are beneficial for cardiovascular health and metabolic function. Trans fats have negative health impacts, including increased risk of cardiovascular disease and cholesterol levels. Polyunsaturated fats, particularly omega-3 and omega-6 fatty acids, are crucial for brain health and development. Plant-based diets can provide a healthy fatty acid profile.

### 3.5.3. Regulatory measures

Regulatory measures are in place to ensure the safety and quality of edible oils and fats, including clear labeling of fat content, limits on harmful compounds, quality standards, regular inspections and testing, consumer education, and bans on partially hydrogenated oils.

## 3.6. Case Studies and real-world applications

Edible oils, rich in monounsaturated and polyunsaturated fats, are essential for maintaining good health. Consuming fruits, vegetables, whole grains, and lean proteins supports overall health. Future directions include sustainable production, nutritional research, innovative processing technologies, regulatory enhancements, and consumer education [52,53].

### 3.6.1. The impact of diet on health outcomes

The impact of diet on health outcomes is significant, as dietary choices can influence the risk of developing chronic diseases such as cardiovascular disease, diabetes, and cancer. Diets high in saturated and trans fats are associated with increased cholesterol levels, inflammation, and a higher risk of heart disease. Conversely, diets rich in monounsaturated and polyunsaturated fats, like those found in olive oil, nuts, seeds, and fatty fish, are linked to improved cardiovascular health, reduced inflammation, and better metabolic function. Additionally, diets emphasizing fruits, vegetables, whole grains, and lean proteins support overall health and can help manage weight, prevent chronic diseases, and promote longevity.

### 3.6.2. Success stories

Success stories demonstrate the positive impact of healthy dietary changes on individual and community health outcomes. For example, the Mediterranean diet, rich in monounsaturated fats from olive oil and polyunsaturated fats from nuts and fish, has been linked to lower rates of cardiovascular disease, improved metabolic health, and increased longevity. Communities that have adopted plant-based diets, emphasizing fruits, vegetables, whole grains, and healthy fats, have shown reductions in obesity rates and chronic diseases. Personal success stories often highlight significant weight loss, improved cholesterol levels, and enhanced overall well-being due to adopting healthier eating habits. These examples underscore the importance of dietary choices in achieving and maintaining good health.

### 3.6.3. Future directions

Future directions in the study and application of edible oils and fats focus on enhancing health benefits, sustainability, and safety. Key areas of development include advancements in sustainable production through eco-friendly agricultural practices and extraction methods to reduce environmental impact and promote healthier oils [54–61].

Ongoing nutritional research explores the effects of various fatty acids and the creation of functional edibles fortified with beneficial fats like omega-3s to support cardiovascular and cognitive health. Additionally, the adoption of innovative processing technologies, such as enzymatic and supercritical fluid extraction, aims to improve oil quality and reduce harmful contaminants.

Strengthening regulatory enhancements is another critical area, with efforts to ensure safety and quality through more stringent limits on harmful compounds and clearer labeling requirements. Finally, increasing consumer education is essential to raise awareness about healthy dietary practices and the importance of choosing the right types of fats, emphasizing the benefits of monounsaturated and polyunsaturated fats while limiting saturated and trans fats.

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## 4. Conclusion

The study and application of edible oils and fats have significant implications for public health, nutrition, and sustainability. By understanding the different types of fats and their health impacts, individuals can make informed dietary choices to support cardiovascular health, reduce the risk of chronic diseases, and maintain overall well-being. Advancements in processing techniques and regulatory measures ensure the safety and quality of edible oils, while sustainable production practices and innovative technologies pave the way for healthier and more environmentally friendly options. Continued research and consumer education are essential to promote the benefits of healthy fats and mitigate the risks associated with harmful ones, contributing to a healthier future for all.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The research was conducted independently, without any direct financial support from entities that could benefit from the findings of this study.

The authors have strived to ensure that the analysis and recommendations provided are unbiased and based on rigorous research and evidence. Any affiliations or previous funding mentioned are disclosed for transparency and do not affect the objectivity of this work

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