

OILS AND FATS AS RAW MATERIALS FOR INDUSTRY

EDITED BY

Divya Bajpai Tripathy, Anjali Gupta, Pooja Agarwal, Anuradha Mishra, and Arvind Kumar Jain

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Preface

In today's world, oils and fats play a crucial role in various industries and applications. From the food industry to cosmetics, from pharmaceuticals to coating industries, these versatile substances have become indispensable raw materials. With increasing concerns about sustainability and environmental impact, there is a growing need to explore alternative sources and utilize biotechnology to harness the potential of oils and fats. This book is divided into 12 chapters, discussing the potential of oil and fats as raw materials for various industrial sectors.

In chapter 1, fundamentals of oils and fats has been covered. Discussion has been made on their various types, ranging from vegetable oils to animal fats, on their chemistry and properties. Understanding the characteristics of different oils and fats is essential to comprehend their applications across industries.

The second chapter of the book is focuses on the advancements in biotechnology that have revolutionized the production and utilization of oils and fats. We explore the role of biotechnology in enhancing yield, improving quality, and developing sustainable processes. The chapter highlights the potential of genetic engineering, enzyme technology, and other biotechnological tools in the field of oils and fats.

Chapter 3 of the book is based on the sustainability of oils and fats over petrochemicals. This chapter insights the concerns about the environmental impact of petrochemicals rise and examines the sustainability of oils and fats as an alternative. Comparison on the ecological footprint of oils and fats with that of petrochemicals and

discuss the advantages and challenges associated with transitioning to renewable sources has been done. The chapter also addresses the importance of sustainable sourcing and production practices.

The fourth chapter explores the extensive use of oils and fats in the food industry. This discusses their role in cooking, flavouring, and texture enhancement, and their impact on product quality. Additionally, the chapter examines the health considerations associated with consuming different types of oils and fats, shedding light on the ongoing debates surrounding their effects on human health.

Chapter 5 investigates the potential of oils and fats as raw materials for surfactants and laundry detergents. Traditional petrochemical-based surfactants can have adverse environmental effects, and this chapter explores the benefits of utilizing renewable sources to produce eco-friendly alternatives. Challenges and opportunities in this emerging field has also been covered.

Cosmetics have long relied on oils and fats for their moisturizing, emollient, and functional properties. Chapter 6 examines the use of oils and fats in the cosmetic industry, ranging from skincare to haircare products and delve into the formulation aspects and discuss the growing demand for natural and sustainable ingredients.

Coatings are essential for protection and enhancement in numerous industries. In seventh chapter, applications of oils and fats as raw materials for coatings has been explored. In addition, their role in providing durability, adhesion, and corrosion resistance, while also considering the sustainability aspects of such coatings have also been discussed.

The eighth chapter focuses on the utilization of oils and fats as raw materials for corrosion inhibitors and biolubricants. We delve into their effectiveness in protecting metal surfaces from degradation and their potential as environmentally friendly lubricants. The chapter discusses the challenges in implementing these alternatives and their benefits for various industries.

The pharmaceutical industry constantly seeks new and innovative solutions, and vegetable oils have emerged as promising candidates. This chapter delves into the unique properties of vegetable oils and their applications in pharmaceutical formulations. From drug delivery systems to excipients, vegetable oils offer numerous advantages, such as improved bioavailability and enhanced stability. We explore the latest research and developments in this exciting field.

As the world strives towards a greener future, the search for sustainable energy sources becomes increasingly crucial. In this chapter, we explore the utilization of non-edible oils as biodiesel. These oils, derived from plants that are not traditionally used for food, offer a renewable and environmentally friendly alternative to conventional fossil fuels. Chapter 10 delves into the production methods, properties, and challenges associated with non-edible oils as biodiesel, shedding light on their potential impact on energy sustainability.

Oils and fats play a significant role in both ecological and economic realms. Chapter 11 examines the intricate relationship between oil and fat production, consumption, and their environmental impact and explores the topics such as deforestation, land use, and the carbon footprint associated with oil production, as well as the economic implications of oil markets and trade. By understanding the

ecological and economic aspects of oils and fats, decisions to foster a sustainable and balanced future can be made.

Corrosion poses a significant challenge across various industries, leading to economic losses and safety concerns. In chapter 12, potential of oils and fats as raw materials for corrosion inhibitors has been explored. This last chapter of the book delve into the unique properties of these substances that make them effective in preventing or reducing corrosion. By examining their mechanisms of action and applications, the possibilities of harnessing oils and fats to mitigate the damaging effects of corrosion have been uncovered.

Throughout this book, editors and authors aim to provide a comprehensive understanding of oils and fats, showcasing their versatility and potential in different fields. From pharmaceutical applications to energy sustainability and environmental considerations, the chapters ahead will shed light on the multifaceted nature of oils and fats. This exploration will inspire further research and innovation, pushing the boundaries of what oils and fats can achieve.

Divya Bajpai Tripathy
Anjali Gupta

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Oil and Fats as Raw Materials for Industry: An Introduction

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Abstract

Worldwide, fats and oils occupy major roles in nearly all industries like food, pharmaceutical, surfactants, biodiesel, agriculture, etc. The major renewable raw materials for the chemical industry are oils and fats, which are lipids. When ingested in sufficient quantities, they serve as a vital component of a healthy diet. Triacylglycerols (TAGs), also referred to as triglycerides, are essentially ester-linked glycerol moieties connected with three fatty acids that make up oils and fats. These fatty acids provide fats with useful properties. Because of the modification in lipids with improved nutritional and functional qualities, scientists and researchers have recently developed a growing interest in fats and oils. Triacylglycerols have a variety of properties and use depending on their structure and lipid composition. Therefore, altering the TAGs of lipids is a method for producing personalized lipids and expanding the range of

their applications. Due to the detrimental health effects of trans fats, which are mostly brought on through partial hydrogenation, interesterification has become the dominant alternative strategy. This chapter provides a wide range of unprocessed fats and oils, along with information on their characteristics, classification, and historical evolution. In addition, the chapter emphasises the applications and difficulties in this field.

***Keywords*:** Fats, oils, raw materials, saturated, unsaturated, applications, triglycerides

1.1 Introduction

“Fatty acids” (FAs) are molecules with long carbon chains in which the hydrogen atoms are connected to carbon atom bonds along with chains bearing carboxyl (-CO) as a functional group. Fatty acids are the building blocks of “fats” and “oils. “Saturated” fats are simple straight chains of carbon (C) atoms having alkanes, i.e., only single bonds between C-atoms, whereas unsaturated fats have alkenes or alkynes, i.e., double or more bonds. As a result, polyunsaturated fatty acids have more than two double bonds between C-atoms while monounsaturated fatty acids only have one double bond [1].

Natural fats and oils are mainly composed of triacylglycerols (TAGs), and the composition and molecular structure of TAGs differ from the physico-chemical and determines functional and nutritional properties of fatty acids, i.e., saturated, mono or polyunsaturated [2]. The suitability of fats and oils are usually determined by their physico-chemical properties. The use of the words “oil and fat” in most languages recognizes the property of being liquid or solid at ambient temperature as the basis for distinguishing between these two classes of products [3]. The molecular structure, melting and crystallization

behaviour, and rheological properties of fats and oils are important for the rational design of lipid materials [4]. It is well known that the properties of fats and oils mainly depend on their triacylglycerol composition, i.e., the unsaturation degree and carbon chain length of the TAGs component fatty acid (FA) molecules [5].

Oils and fats are organic compounds with carboxylic acids as active elements. As a renewable source, oils and fats from plant seeds and animal tissues are used to manufacture petroleum products in industries [6]. Fats and oils are a “great source of energy (9 kcal/g) and essential fatty acids such as linoleic acid (18:2), linolenic acid (18:3), EPA (20:5) and DHA (22:6) to humans” [7]. Fats have a vital role in meat products, influencing organoleptic like palatability, texture and flavour, and technological aspects like cooking loss, emulsion stability, water holding capacity and rheological properties. In comparison to animal fats, vegetable oils have a higher ratio of unsaturated to saturated fatty acids and do not include cholesterol [8]. Being a source of important fatty acids and fat-soluble bioactive substances, vegetable oils and fats are a crucial part of the human diet.

Palm oil, sunflower oil, rapeseed oil and soybean oil are the four edible vegetable oils that are traded the most on a global scale. Interest in alternate sources of vegetable oils has developed due to the current demand for oils and fats for human consumption, with an emphasis on nutritious eating and new industrial uses [9]. Studies on the chemical and physical characteristics of oils and fats produced from distinctive oil plants have been done in order to identify substitute lipid sources with high nutritional value as well as to enhance commercial applications [10]. Due to the presence of carotenoids and chlorophyll pigments, vegetable oils are often clear and have a yellow or green colour [7]. Dietary sources of fats that play significant and

varied roles in biological processes include vegetable oils and animal fats. Triacylglycerols are important components of oils and fats, and the profiles of various oils and fats varies significantly. For nutritional evaluation, quality assurance, and ensuring the safety of oils and fats, TAG profiles are required [11].

According to O'Brien (2009), "edible oils and fats consisting of esters of glycerine and fatty acids (>90%) are structurally distinguished from triglycerol based on their chain length, the position of the double and cis/ trans bonds as well as the relative ratios of saturated and unsaturated fatty acids, i.e., number and position of double bonds" [9]. In human nutrition, meats, fats, edible oils, fish, dairy products and nuts are the main sources of lipids in the human diet. Researchers have found that "dietary fatty acids play an important role in cholesterol metabolism and thus may be associated with cardio-vascular disease (CVD)" [12]. As we gain more knowledge about the relation between dietary fats and fatty acids and chronic diseases, particularly coronary artery disease (CAD), the significance of edible fats and oils in health and illness continues to develop [13].

In total, India grows nine different oil seed crops, seven of which are used to make edible oils, including sunflower, safflower, oilseed rape (mustard), niger, sesame, soybean, and peanut. Linseed and Castor, on the other hand, are non-edible oil seeds. Significant amounts of edible oil are also produced by maize germ, cotton seed, and rice bran [13]. Fats and oils are widely used in domestic and industrial settings, as well as being the most frequent contaminants in wastewater. Because they are typically removed by physical processes in sewage treatment plants, these substances are left behind in large quantities that are challenging to discard and process [13]. Fats and oils are significant organic components of municipal and industrial

wastewaters, although it is unclear how they behave exactly during the treatment process [14]. Although recent advances in this sector have made it possible to remove a sizable part of oil from wastewater, biological treatment of oily wastewater is not well developed [15]. Anaerobic digesters of various designs have been researched for the treatment of sludge and oil simultaneously. For instance, anaerobic co-digestion of food waste, oils and fats with sewage sludge [16], long-chain fatty acids of oils and fats with municipal sludge [17], and aerobic co-digestion of sludge with oils and fats were also examined [18, 19].

1.2 Classification of Oils and Fats

Essential nutrients in a good diet include oils and fats. The terms oil and fat differ by the states of triglycerides, i.e., at room temperature, liquid triglyceride is termed as oils whereas at solid state it is fat [20]. Most commonly used oils and fats have long chain fatty acids, i.e., typically 8 to 20 carbon atoms, mostly having an even number of carbons; however, an odd number of carbon long chains is found mostly in animal fats. Such fatty acids contain -CH_3 (methyl) group at one end and -COOH (carboxylic acid) group at other end. An ester bond of triacylglycerol is formed by the reaction of this carboxylic group with the hydroxyl (-OH) group present on the glycerol molecule [20].

- Fats and oils
  - Long chain
    - Long chain saturated 14-18
      - Myristic acid
      - Palmitic acid
      - Stearic acid
        - Butter lard
        - Tallow palm
        - Salmon
    - Mono-unsaturated
      - Omega-9
        - Olive
    - Poly-unsaturated
      - Omega-6
        - Corn Soyabean, Sunflower
      - Omega-3
        - Linseed and Fish
  - Medium chain
    - Medium-chain saturated 8-12
      - Caprylic acid
      - Caproic acid
      - Capric acid
      - Lauric acid
        - Coconut

Figure 1.1 Classification of fats and oils.

The three main groups of fatty acids (Figure 1.1) can be divided according to chain length:

1. Long-chain fatty acid
2. Medium-chain fatty acid
3. Short-chain fatty acid

1.2.1 Long-Chain Fatty Acid

Long-chain fatty acids (LCFAs) comprise 13 to 21 carbon atoms having an aliphatic end, as a result of hydrolysis of neutral triglycerides. Palmitate, stearate, and oleate are the three most abundant LCFAs present in the system where digestion takes place in the absence of oxygen termed as anaerobic digesters [21].

1.2.1.1 Long-Chain Saturated Fatty Acid

Saturated fats are solid at room temperature, which is why they are also called solid fat. It is primarily present in "foods of animal origin, like milk, cheese, and meat. Poultry and fish contain less saturated fat than red meat [22]. Saturated fats are also found in tropical oils, such as coconut oil, palm oil, and cocoa butter. Tropical oils like saturated fatty acids are also found in many snacks and non-dairy foods, such as coffee creamer and whipped toppings. Foods made with butter, shortening (pastries and cakes, cookies, and other similar desserts) or margarine, have higher saturated fats which can elevate cholesterol levels. A healthy diet contains less than 10% of daily calories from saturated fat" [22].

Below are the most common long-chain saturated fatty acids.

1.2.1.1.1 Stearic Acid (18 Carbon Atoms)

Stearic acid is a long-chain saturated fatty acid with an 18-C framework and molecular formula $C_{18}H_{36}O_2$ (Octadecanoic acid), Figure 1.2 [23]. It is waxy-solid in texture. Stearic acid is present in “fats and oils of various plants and animals and is one of the useful types of saturated fatty acids, and a major constituent of cocoa butter and shea butter” [23].

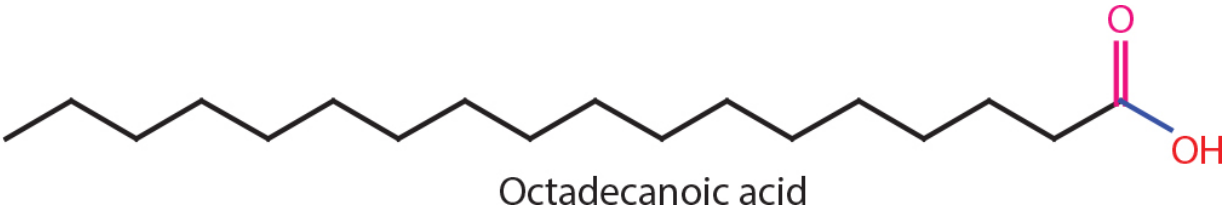

Figure 1.2 Structure of Octadecanoic acid.

1.2.1.1.2 Palmitic Acids (16 Carbon Atoms)

Palmitic acid is a long-chain saturated fatty acid with a 16-C framework and molecular formula $C_{16}H_{32}O_2$ (Hexadecanoic acid), Figure 1.3. Palmitic acid is naturally present in “palm oil and palm kernel oil, milk, butter, cheese, and meat” [24].

1.2.1.1.3 Myristic Acid (14 Carbon Atoms)

The saturated long-chain fatty acid having 14-C framework forms a myristic acid with molecular formula $C_{14}H_{28}O_2$ (Tetradecanoic acid), Figure 1.4. The sources of myristic acid are palm oil, coconut oil, and butter fat [25, 26].

1.2.1.2 Unsaturated Fatty Acid

At normal temperature, fats and unsaturated fatty acids are liquid. This type of fatty acid is generally present in oils from plants and helps to improve cholesterol levels [27]. Unsaturated fats are further classified as Monounsaturated fat and Polyunsaturated fat.

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