Industrial Uses of Vegetable Oils

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Preface

Vegetable oils are used in various industrial applications such as emulsifiers, lubricants, plasticizers, surfactants, plastics, solvents and resins. Research and development approaches take advantage of the natural properties of these oils. Vegetable oils have superb environmental credentials, such as being inherently biodegradable, having low ecotoxicity and low toxicity towards humans, being derived from renewable resources, and contributing no volatile organic chemicals.

United States agriculture produces over 25 billion pounds of vegetable oils annually. These domestic oils are extracted from the seeds of soybean, corn, cotton, sunflower, flax, and rape. Although a major part of these oils are used for food products such as shortenings, salad and cooking oils and margarines, large quantities serve feed and industrial applications. Other vegetable oils widely used industrially include palm, palm kernel, coconut, castor, and tung. However, these are not of domestic origin. The three domestic oils most widely used industrially are soybean, linseed from flax, and rapeseed.

Nonfood uses of vegetable oils have grown little during the past 40 years. Although some markets have expanded or new ones added, other markets have been lost to competitive petroleum products. Development of new industrial products or commercial processes is the objective of continued research in both public and private interests. The following selected examples illustrate progress in identifying and developing new technologies based on vegetable oils.

Great progress has been made in understanding of the biochemical basis for biosynthesis of oils containing fatty acids. This biochemical information is in turn used to identify and isolate genes that are needed to make these oils. By genetically engineering the introduction and expression of these genes, domesticated crops that can produce these potentially useful fatty acids have been engineered and are continuing to be developed to produce an ever wider range of novel oils.

Chapter 1 explains the biochemical changes that can be introduced to alter fatty acid composition. It also discusses industrial oils that have been developed through genetic engineering, as well as some that have been developed on the laboratory scale, but have not yet been introduced commercially.

Recent environmental awareness and depletion of world fossil fuel reserves have forced to look a substitute for mineral oils with the biodegradable fluids such as vegetable base oils and certain synthetic fluids in grease formulations. The nontoxic and readily biodegradable characteristics of vegetable oil based greases pose less danger to soil, water, flora, and fauna in case of accidental spillage or during disposal. Biodegradable greases are particularly useful in open lubrication systems where the lubricant is in direct contact with environment, and total loss lubricants like railroads, where immediate contact with the environment is anticipated. Chapter 2 discusses the various components (base oils, thickeners and additives), functional properties, and characteristics of biodegradable greases. The base oils included synthetic esters, castor, rapeseed, and soybean oil.

Chapter 3 reviews some of the advantages and disadvantages of using vegetable oil lubricants and their availability. Some of the history in the development of vegetable-based engine oils and their current status is described. The requirements for further development and penetration of the petroleum based engine oil market are discussed.

Besides transesterification to alkyl esters, three other approaches—dilution with conventional, petroleum-based diesel fuel, microemulsions (co-solvent blending), and pyrolysis—have been explored for utilizing vegetable oils as fuel. However, as the mono-alkyl esters of vegetable oils and animal fats—biodiesel—are the only approach that has found widespread use (and, accordingly, the vast majority of research papers deal with this approach), Chapter 4 focuses on such mono-alkyl esters in terms of use, properties, economies, and regulatory issues.

Chapter 5 presents a background on home heating systems and highlights recent research to develop renewable biofuels for home heating applications. Petroleum-based liquid home heating oil is used to heat over 8 million homes in the U.S., predominantly in the northeastern U.S. This comprises approximately 6.6 billion gallons of fuel oil annually. With recent rises in petroleum prices to over $50 per barrel and anticipated future price increases as petroleum resources become less available, many applications that depend on petroleum are searching for alternatives. Additional concerns over environmental issues involving sulfur and nitrogen oxide emissions from oil-based home heating systems have sparked a search for alternative fuels to supply this market.

Polyurethanes are the most versatile group of polymers which can be used in the form of foams, cast resins, coatings, adhesives and sealants. Polyols used in the polyurethane industry currently exceed 2.4 million tons/year in the U.S. To use natural oils as raw materials for polyurethane production, multiple hydroxyl functionality is required. Castor oil has hydroxyl functionality naturally built in, thus it has received extensive exploration as polyurethane building blocks, such as casting resins, elastomers, urethane foams, and interpenetrating networks. Hydroxyl functionality can be introduced synthetically in other natural oils. This process involves a number of approaches and has been studied extensively by scientists around the world, but commercial production of oil-based polyols has been scarce. Chapter 6 discusses the four main approaches for the hydroxylation of vegetable oils.

In Chapter 7, the authors summarize the type of natural composites reinforced with different fibers along with different composite molding methods. The Solid Freeform Fabrication Method and its advantages are included in the discussion.

Technologies that have improved the use of oils in coatings are highlighted in Chapter 8.

The petroleum shortage in the 1970s stimulated research on vegetable oil-based inks as a substitute for petroleum based products. Vegetable oils are mainly used in paste inks; therefore the role of vegetable oils in the paste ink formulations and their environmental properties are the main subject of Chapter 9.

Chapter 10 explains that vegetable oils provide a renewable source of fatty acids that can serve as raw materials for the production of numerous surfactant compounds. Structural modification of the fatty acids can impart unique physical properties that alter the performance of the product in a predictable manner. Chemical functionality can be introduced at the carbonyl carbon or along the carbon chain by appropriate selection of reactants, catalysts, and reaction conditions. A tremendous diversity of products is available with these oleochemical substrates. In addition, vegetable oils provide a favorable alternative to petrochemical feedstocks.

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Contents