



ENVIRONMENTALLY FRIENDLY AND BIOBASED LUBRICANTS



edited by
Brajendra K. Sharma
Girma Biresaw



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Preface

Research on environmentally friendly and biobased lubricants is increasing due to environmental concerns, rapidly depleting petroleum reserves, and stringent government regulations. Vegetable oil-based lubricants are finding applications in many environmentally sensitive and total loss applications ranging from hydraulic oils to grease. They possess excellent biodegradability, lower ecotoxicity, higher viscosity index, good boundary tribological properties, lower volatility, and higher flash points compared to petroleum base oils. The global lubricant demand is growing at about 2% per year and it will reach 42.1 million metric tons by 2017. According to a study done by the Freedonia Group, the demand for biobased lubricants is on the rise, from a share of 0.3% in 1997 to 0.6% in 2010, with a projected share of 1.2% by 2017. Clearly, there is room in the market for the expansion of biobased lubricants, where the annual demand is growing at a rate of 16.3% in the European market. This contrasts with the much slower rate of increase of the consumption of lubricants as a whole. Additionally, natural products have an inherent advantage in the food-grade lubricant market, which is projected to expand at about 5% annually, with much of the growth in the United States.

There exists a large amount of scattered information on environmentally friendly and biobased lubricants. However, as in any field of scientific endeavor, there is a need for an occasional pause, assessment, and refocus of research accomplishment and communication in terms of our research paradigms. We hope to at least partially address this need for reflection and consideration through this book. During the Society of Tribologists and Lubrication Engineers (STLE) annual meetings, leading researchers from around the world are engaged in unraveling the importance and the relevance of this area. They present their latest research findings in technical sessions on environmentally friendly fluids and biobased lubricants. These technical sessions were always such a huge success that the need to take the next logical step—a text that synthesizes the burgeoning knowledge in this field—was born during the 2012 STLE Annual Meeting. Allison Shatkin, senior editor of CRC Press/Taylor & Francis invited us to edit a book on this topic, and the editors enthusiastically accepted the challenge and immediately started working on the project.

Selected authors (who presented their work in the environmentally friendly fluids and biobased lubricants technical sessions of STLE Annual Meetings) and other prominent researchers were invited to submit manuscripts on research topics that have been shared at various technical sessions for the past several years. After a thorough peer review process, 21 manuscripts were selected for the current volume. Authors were encouraged to critically analyze respective chapters beyond simple reviews of existing research in their area of expertise. We hope the resulting array of viewpoints provides a valuable tool for those interested in environmentally friendly and biobased lubricants. Varying perspectives of research experiences and concerns have been gathered in this book in order to provide the reader with a sense of both appropriate applications and development needs in the field. Specific case histories demonstrating the uses and values of various commercially available biobased lubricants are included. Laboratory development of newer environmentally friendly fluids, field studies of mature biobased lubricants, biodegradability studies, and future research needs are identified. Most importantly, the chapters provide a critical assessment of gaps and weaknesses in the current state of knowledge on these subjects and also provide direction for future research.

This book offers a review, a synthesis, and a critical assessment of the major issues in the field of environmentally friendly fluids and biobased lubricants by some of the leading scientists in the field. It provides a collective review of developments and approaches being used in this emerging area of lubrication. The 21 chapters are logically grouped into five sections. Section I consists of five chapters examining advanced environmentally friendly base oils and feedstocks. This section covers recent advances in farnesene-derived base oils, estolides, epoxidized soybean oils, isostearic acid, and new plant oil-based monomers and polymers. Section II, which is on biobased hydraulic

lubricants and biodegradability, has four chapters. These give the readers a flavor of performance and technical requirements of low-environmental impact lubricants along with their biodegradability and ecotoxicity evaluations; comparison of current standards for environmentally acceptable lubricants to the actual requirements of the environment and reproducibility of biodegradation test methods; and availability of different types of environmentally preferable fluids, their strengths, limitations, and comparable performance; and recommend best maintenance practices for prolonged fluid and equipment life. Section III contains three chapters on chemically/enzymatically modified environmentally friendly base oils. The first two chapters in this section explore the enzymatic route as a biocatalyst for biolubricant production, while the last one presents chemical methodologies for producing ester-based lubricants. Section IV comprises four chapters dealing with vegetable oil-based environmentally friendly fluids. The first two chapters in this section discuss some of the drawbacks of vegetable oil-based lubricants, such as poor thermo-oxidative stability, low-temperature flow properties, biological deterioration, and hydrolytic stability and ways to rectify these issues. The last two chapters give specific examples of applications of vegetable oils for producing lubricant additives by chemical modifications followed by their performance evaluations. Section V contains five chapters on additives for environmentally friendly fluids. This section covers topics such as fatty acid friction in nanoscale contact, additives used in formulations of biodegradable lubricants, nano-TiO₂ as additive for solid and liquid lubricants, biodiesel as lubricant and solvent, and anticorrosion effects of starch-oil dry lubricants.

This book will make an excellent reference for students, chemists, scientists, engineers, tribologists, professionals, and policy makers in the academia, the government, or the corporate world working or entering the field of environmentally friendly fluids and biobased lubricants. With the information contained in this book, it is our hope that future research will lead to more cost-effective commercial biobased products with performance equivalent to or better than that of petroleum-based ones. We are very grateful to a large number of individuals for their assistance with this book. Special thanks to all the contributors, for their enthusiasm, commitment to, and cooperation in the project and for sharing their original research or for their review of the current knowledge. Without their commitment, encouragement, suggestions, and assistance, this project would not have taken shape into this book. We sincerely thank each and every one of the contributing authors, who had to hear our pleas to meet deadlines and worked hard to finally create this book. We are also grateful for the invaluable comments and suggestions made by the reviewers, which significantly improved the quality, the clarity, and the content of the chapters. Last but not least, we extend our sincere thanks to Allison Shatkin, senior editor of CRC Press/Taylor & Francis, who conceptualized this idea, and Jill J. Jurgensen, Laurie Oknowsky, and Hayley Ruggieri of CRC Press for their timely efforts in publishing this book.

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Prior to 2009, Dr. Sharma was a research associate in the Department of Chemical Engineering at Pennsylvania State University and conducted research at the National Center for Agricultural Utilization Research, Agricultural Research Service, U.S. Department of Agriculture, Peoria, Illinois, as a visiting research chemist on joint appointment. In this position, he conducted innovative research on developing biobased lubricants/additives through chemical modifications of vegetable oils for seven years. Before that, he conducted research on petroleum base oils as a post-doctoral research associate at State University of New York–College of Environmental Science and Forestry, Syracuse, New York. Dr. Sharma received a PhD in chemistry from the Indian Institute of Petroleum/Hemwati Nandan Bahuguna Garhwal University (India).

Dr. Sharma is a vice chair of Environmentally Friendly Fluids Technical Committee (EFFTC) of the Society of Tribologists and Lubrication Engineers (STLE) and a member of the American Chemical Society. Earlier, he served as paper solicitation chair for STLE’s EFFTC and Lubrication Fundamentals Technical Committees. He is an associate technical editor of American Oil Chemists’ Society’s *Journal of Surfactants and Detergents*. Dr. Sharma holds five issued patents on biobased lubricants/additives and has authored/coauthored more than 140 peer-reviewed articles, proceedings, book chapters, and technical reports and more than 130 scientific abstracts.

Girma Biresaw received a PhD in physical organic chemistry from the University of California–Davis, and spent 4 years as a postdoctoral research fellow at the University of California–Santa Barbara, investigating reaction kinetics and products in surfactant-based organized assemblies. He then joined the Aluminum Company of America as a scientist and conducted research in tribology, surface/colloid science, and adhesion for 12 years. He joined the Agricultural Research Service (ARS) of the U.S. Department of Agriculture, in Peoria, Illinois, in 1998 as a research chemist, and became a lead scientist in 2002. At ARS, he conducts research in tribology, adhesion, and surface/colloid science in support of programs aimed at developing biobased products from farm-based raw materials. He has received more than 150 national and international invitations, including requests to participate in and/or conduct training, workshops, advisory, and consulting activities. He is the lead organizer of the “Biobased Lubricants” sessions of the Non-Ferrous Technical programs at the STLE Annual Meetings. He is also the senior organizer and chair of the biannual international symposium series “Surfactants in Tribology,” held at various locations around the world in conjunction with the “Surfactants in Solution” symposium series. He is a fellow of STLE, and a member of the editorial board of the *Journal of Biobased Materials and Bioenergy*. Dr. Biresaw has authored/coauthored more than 270 invited and contributed scientific publications, including more than 80 peer-reviewed manuscripts, six patents, five edited books, more than 40 proceedings and book chapters, and more than 140 scientific abstracts.

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