INFORM May 2022 Volume 33 (5)

INFORM

International News on Fats, Oils, and Related Materials

SUSTAINABLE PALM OIL

ALSO INSIDE:

2022 AOCS Award Winners

Palm oil and cancer metastasis

Green nanoemulsions

AOCS


Best In
EDIBLE OIL
FILTRATION
VERTICAL
PRESSURE LEAF FILTER
HORIZONTAL
PRESSURE LEAF FILTER
CANDLE FILTER
BACK WASH TYPE
TUBULAR
CENTRIFUGE
FILTER
SINGLE &
MULTIBAG
POLISHING FILTER
FILTER
ELEMENTS
Sharplex®
2500
World Wide Installations
SHARPLEX FILTERS (INDIA) PVT. LTD.
AN ISO 9001:2008, 14001:18001 COMPANY
R-664, T.T.C. Industrial Area, Thane Belapur Road, Rabale,
MIDC, Navi Mumbai - 400 701, India.
Tel: +91 9136921232 till 9136921239 / 022-27696322/31/39
Fax : 022-27696325
Toll Free No. – Spares Dept.- 1800226641
E-mail : sales@sharplexfilters.com
www.sharplex.com
CE

CONTENTS

DEPARTMENTS

INFORM
www.aocs.org

AOCS MISSION STATEMENT
AOCS advances the science and technology of oils, fats, proteins, surfactants, and related materials, enriching the lives of people everywhere.

INFORM
International News on Fats, Oils, and Related Materials
ISSN: 1528-9303 IFRMEC 33 (5)

The views expressed in contributed and reprinted articles are those of the expert authors and are not official positions of AOCS.

INDEX TO ADVERTISERS

**Corporate member of AOCS who supports the Society through corporate membership dues.*

2710 South Boulder Drive
P.O. Box 17190
Urbana, IL 61803-7190 USA
Phone: +1 217-359-2344
Fax: +1 217-351-8091
Email: publications@aocs.org

Formerly published as *Chemists' Section*, *Cotton Oil Press*, 1917–1924; *Journal of the Oil and Fat Industries*, 1924–1931; *Oil & Soap*, 1932–1947; news portion of *JAOCS*, 1948–1989. The American Oil Chemists' Society assumes no responsibility for statements or opinions of contributors.

Inform (ISSN: 1528-9303) is published 10 times per year in January, February, March, April, May, June, July/August, September, October, November/December by AOCS Press, 2710 South Boulder Drive, Urbana, IL 61802-6996 USA. Phone: +1 217-359-2344. Periodicals Postage paid at Urbana, IL, and additional mailing offices. **POSTMASTER:** Send address changes to *Inform*, P.O. Box 17190, Urbana, IL 61803-7190 USA.

Subscriptions to *Inform* for members of the American Oil Chemists' Society are included in the annual dues. An individual subscription to *Inform* is $195. Outside the U.S., add $35 for surface mail, or add $125 for air mail. Institutional subscriptions to the *Journal of the American Oil Chemists' Society* and *Inform* combined are now being handled by Wiley. Price list information is available at http://olabout.wiley.com/WileyCDA/Section/id-406108.html. Claims for copies lost in the mail must be received within 30 days (90 days outside the U.S.) of the date of issue. Notice of change of address must be received two weeks before the date of issue. For subscription inquiries, please contact Julie May at AOCS, julie.may@aocs.org. AOCS membership information and applications can be obtained from: AOCS, P.O. Box 17190, Urbana, IL 61803-7190 USA or membership@aocs.org.

Three paths forward for sustainable palm oil

Stacy W. Kish

Palm oil has become the most common source of oil in food today. Every year, global consumption exceeds 70 million metric tons, and the demand is only expected to rise, due in part to palm oil's versatility. Food products from ramen to oat milk incorporate palm oil, as do a diverse array of commercial items, like shampoo and lipstick or biodiesel fuel.

- **The demand for palm oil is expected to increase in the coming years, but the industry is faced with a dilemma—how to meet global requirements without engaging in deforestation and the destruction of peatland to expand the size of oil palm plantations.**
- **Government and non-profit organizations are united in certifying plantations in the use of sustainable practices to limit detrimental environmental effects of farming this commodity.**
- **Researchers are also exploring ways to increase the oil yield, squeezing out more of the product from the land that is already under cultivation.**
- **A myriad of companies have recently formed, specializing in fermentation for bio oil production that replicates the desired characteristics of palm oil to meet industry standards.**

The crop is versatile too. Oil palm trees can produce up to 10 times more oil than other vegetable oil crops. Fruit from the oil palm tree can be harvested every 10 to 14 days, with one tree producing 40 kilograms of oil every year, for up to 30 years. Palm oil accounts for 36% of global vegetable oil consumed. Oil palm trees also produce more oil per unit of cultivated land than other vegetable oil crops. In fact, if all vegetable oil provisions were turned over exclusively to palm oil, it would require 76.87 million hectares of land, or about twice the size of California. For this reason, palm oil is one of the fastest-growing sub-sectors of the global agriculture economy.

Originating in West Africa, oil palm trees have been introduced to tropical regions around the world. Today, Malaysia and Indonesia produce about 90% of global palm oil output. This important agricultural crop has had a stabilizing effect on the economy of both countries. In 2020, Sabah, a state on the northern tip of Borneo's east Malaysia, produced 5 million tons of palm oil, or 6% of the global palm oil production. This impressive output has generated the equivalent of more than $230 million to the country's economy. Across southeast Asia, 4.5 million people participate in the palm oil economy, lifting them out of poverty and opening access to better housing and education.

THE DARK SIDE OF PALM OIL

To keep up with global demand, tropical rainforests and peatlands are increasingly being cleared for oil production. The economic gains of palm oil come at a steep cost to the environment. Tropical forests and peatlands act like sponges, absorbing carbon dioxide, a greenhouse gas. According to the United Nations Environment Programme (https://tinyurl.com/wuumsfh6), 55% of Indonesia's tropical forests have been lost in the past four decades, while Malaysia has lost nearly 20% of its old-growth forest in the past two decades.

FIG. 1. Deforestation along an oil palm plantation.

According to Erik Meijaard, conservation science professor at the University of Kent, in Canterbury, United Kingdom, palm oil cultivation has had a profound effect on the entire region (https://tinyurl.com/2u3ezf3t). Beyond driving deforestation, forest clearance reduces soil fertility, water quality in the surrounding fisheries, water regulation and supply, as well as biodiversity. In addition, deforestation leads to an increased human and wildlife conflict.

The slash-and-burn practices that are used to clear forests and peatland release an estimated one billion tons of carbon dioxide into the atmosphere. The escaping carbon contributes to planetary warming. The fires also release thick plumes of pollutant-laced smoke that choke the region. In Indonesia, more than 900,000 people were hospitalized with respiratory problems due to smoke inhalation from the nearby fires in 2019 (https://tinyurl.com/3r2n76zs).

Last fall, during the COP26 climate summit, 100 nations, including Indonesia and Malaysia, signed a pledge to halt deforestation. While palm oil production is responsible for less than 1% of deforestation globally, it is a major contributor to this practice in tropical regions. To address this concern, conservationists have joined forces with local governments, farmers, and corporations, like Ferrero and General Mills.

These groups are eager to slow the rate of deforestation through sustainable farming practices and increased oil yield. New research is also exploring approaches to optimize fermentation processes to generate a bio oil that can replace palm oil and ensure oil is available for consumer goods without the additional environmental harm.

FIG. 2. Oil palm fruit.

THE PATH TO SUSTAINABILITY

Palm oil growers are keen to decouple their production from deforestation and have begun embracing sustainable agricultural practices. The Roundtable on Sustainable Palm Oil (RSPO) (https://rspo.org), a non-profit organization that unites stakeholders while setting standards, accreditation, and process requirements to ensure sustainable practices are transparent and effective across the palm oil production chain.

RSPO certification is meant to transform the market for palm oil by decreasing the impact of agricultural practices on the environment and making sustainable palm oil more common and accepted by manufacturers. As of 2014, RSPO-certified growers account for 19% of palm oil production, but the road to certification is uneven.

While large companies may have the resources to obtain RSPO certification, small- and medium-sized growers often struggle to achieve this goal. Non-profits, like Forever Sabah (https://www.foreversabah.org), based in Sabah, Malaysia, are helping small growers adopt better farming practices to improve their readiness for certification. By achieving sustainable certification, small- and medium-sized farmers can improve their productivity and gain access to larger markets for their products.

In addition to the RSPO, the Sabah region of Malaysia has launched the Jurisdictional Certification of Sustainable Palm Oil (JCSPO). The program, which began in 2015, has a goal of achieving 100% ethical, green-certified palm oil production by 2025. With the JCSPO in hand, Malaysian palm oil producers will be more aligned with RSPO certification, which should accelerate their ability to obtain certification.

In a 2022 Reuter's article (https://tinyurl.com/bdhtkhcy), Frederick Kugan, the Sabah state forestry department's chief conservator, noted that 24% of the region's palm oil is now RPSO-certified. This approach is now being explored in other regions of Malaysia.

These efforts are encouraging, but a 2018 study (https://www.pnas.org/content/115/1/121) reveals that while deforestation is on the decline, efforts have not been as effective for slowing peatland clearance. In addition, these practices are more commonly adopted by older plantations that lack forest land in which to expand.

GATHERING THE LAST DROP

The demand for palm oil is anticipated to increase 46% beyond current need. In addition to adopting sustainable agricultural practices, researchers are exploring ways to reduce the gap between the actual oil harvested to the potential yield available. They aim to leverage expertise in production, agronomic science and the environment to bring real solutions that could have an impact across many sectors of the palm oil economy.

A 2021 study (https://doi.org/10.1038/s41893-021-00700-y), published in the journal *Nature Sustainability,* examined palm oil production on Indonesian oil plantations. The study found current yield is only 62% of the total attainable oil at large plantations and 53% at smaller outlets. To close the gap between what an operation can and does capture, the scientists sought an attainable yield of 70% (an increase of 8% on large plantations and 17% for smaller operations).

The researchers identified different cultivation practices, like weed control, pruning techniques and nutrition application, as initial steps to reach the identified attainable yield. Their work also suggests improved harvest methods could increase yield. The model indicates these efforts would save 2.6 million hectares of forests and peatlands. It would also prevent the release of 732 metric tons of carbon dioxide equivalent from the conversion of these ecosystems into plantation.

To actually make this happen and achieve these goals will require education and extension efforts, especially for small plantations. Today, researchers are working with producers, non-government organizations and government officials to fine-tune policy to promote investment in agriculture research that reconciles economic and environmental goals and establishes these management techniques on the ground.

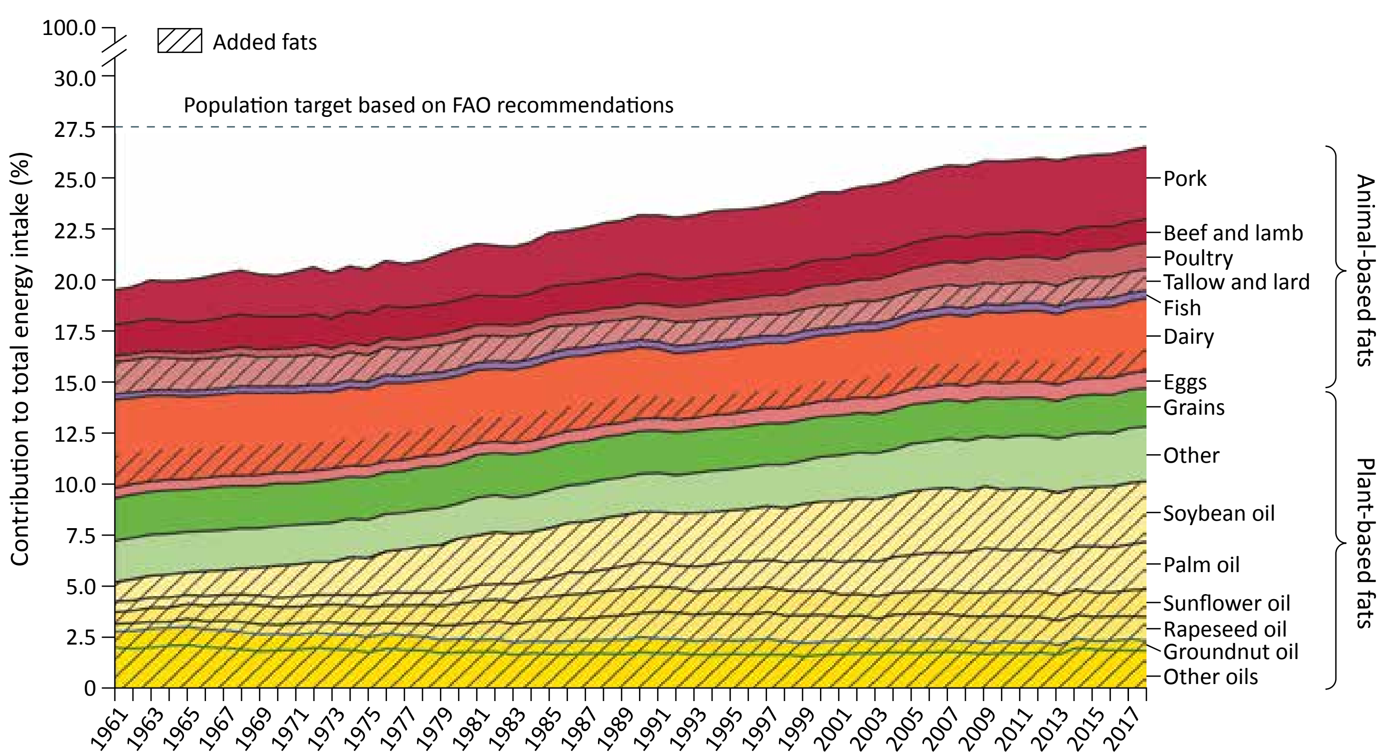


FIG. 3. Historical contribution of different plant and animal sources of fat to global average fat supply per person (1961–2018).
Source: Bajželj, *et al., Lancet Planet Health, 5*, 9, E644-E653, 2021.

Making non-meat, meaty

Bio oil producers may have an ace up their sleeve.

The demand for protein-alternative products to replace meat are growing in popularity. According to the Good Food Institute (https://tinyurl.com/7efr5wuy), next-generation protein-alternative meat, eggs and dairy products are a growing $7 billion market. In particular, the market for plant-based meat is worth $1.4 billion, increasing in sales by more than $430 million from 2019 to 2020.

Perhaps one of the biggest hurdles this sector has to address is recreating the satisfying texture and taste of meat. Meat is a mixture. It contains 20% protein and 10% fat. Current plant-based meats use coconut oil to replace the fat content, but coconut oil does not produce the flavor of meat. To compensate, these products often disregard current trends and contain a litany of chemicals in the ingredient list to match the flavor requirements. Because bio oil is so similar to palm oil, it could produce a desirable mouthfeel and flavor for plant-based protein products.

A new company highlighted in a 2022 Tech Crunch article (https://tinyurl.com/yckz2nre) is focused on tackling the plant-based meat market. Yali Bio (https://www.yalibio.com) is developing a microbial strain library and is testing them out to find the right match. Microbe-produced fats may be the key to revolutionizing a dietary shift from animal-based food to sustainable plant-based foods. As more plant-based protein products begin to taste and feel like meat, it could be the key to moving meatless products from the store shelves to the check-out line at your local grocery store.

FIG. 4. Meat-free vegan steaks.

YEAST TO THE RESCUE?

Despite efforts to curb deforestation and improve product yield, sustainable palm oil faces a difficult path forward. Finding an agricultural alternative is also frustrating. Other options, like coconut oil, produce a lower yield with an even greater environmental impact when production is scaled to meet the industry need. Corn and soybean are non-tropical oils options, but these crops require additional processes to meet the yield of palm oil.

Numerous synthetic biology companies are exploring opportunities to manufacture bio oil through fermentation processes similar to brewing beer. Fermentation is a biochemical reaction that has been used for generations to produce everything from yogurt to ethanol. Organisms, like bacteria or yeast, power the process by extracting energy from carbohydrates or other sugars and converting it into the desired byproduct. Bio oil fermentation takes place in large bioreactors. The microorganisms, often yeast, convert agricultural feedstocks into bio oils that have a lipid profile that mimic the characteristics of palm oil without the environmental implications of growing palm trees. Synthetic biology companies are now exploring various approaches to fermentation to produce a bio oil with the right characteristics at the right cost to meet industry needs.

THE MANY FLAVORS OF FERMENTATION

Located in the heart of Manhattan, C16 Biosciences (https://www.c16bio.com) is optimizing conditions to brew alternative oils, fats and lipids. The company is using genetically-modified strains of yeast to produce a bio oil that is chemically near identical to palm oil. The company has recently received a $20 million Series A round of investment from Breakthrough Energy Ventures. C16 Biosciences first plans to tackle the personal care market with its bio oil product. Clean ingredients are in demand for personal care products and bio oil addresses this need. Personal care products are also a good first step for bio oil production. These products have less stringent regulatory requirements than food products.

Locus Fermentation Solutions (https://locusfs.com), a biotech conglomerate based in Solon, Ohio, USA, is already producing palm-free ingredients using patented production process that leverage bioinformatics and fermentation technology. In their process, microbes are fed renewable raw materials, like canola and corn, to produce sophorolipids, a biosurfactant. Unlike synthetic surfactants, the sophorolipids have a lower toxicity and higher biodegradability.

"We launched Locus Performance Ingredients in July 2020, to replace legacy chemical surfactants used in product formulations with safer, sustainable, low-carbon, high-performance biosurfactants," said Tim Staub, CEO of Locus Performance Ingredients, a subsidiary located in Bon Air, Virginia, USA. "Our technology and resulting sophorolipids are multifunctional, highly efficacious and USDA BioPreferred certified 100% bio-based."

Locus Performance Ingredients plans to create a palm-free bio oil that has a zero carbon footprint. The company uses crops grown on established agricultural land for renewable energy in its production process. According to Staub, the company can scale rapidly anywhere in the world where the feedstocks, electricity and water are available.

"Our innovative, very-low-carbon modular fermentation platform allows us to rapidly scale as needed near end-use markets, further reducing the carbon impact of long supply chains," said Staub. "This allows formulators to simultaneously simplify their formulas and increase the bio-based content and sustainability of their products while improving performance."

The company has joined into a globally exclusive distribution agreement with Dow Chemical. It is now selling their product in a series of personal care products found in and marketed by multiple consumer packaged goods (CPG) companies. They are also exploring collaborations with other applications, from industrial water treatment to textiles pulp and paper production.

AOCS MEETING WATCH

July 31–August 3, 2022. Edible Oil Products Processing Course, Fats and Oils R&D Center LLC, College Station, Texas, USA. (https://fatsandoilsrnd.com/annual-courses/)

October 4-6, 2022. Sustainable Protein Forum, Millennium Knickerbocker Hotel, Chicago, Illinois, USA and Online.

August 27–September 1, 2022. World Congress on Oleo Science, hosted by the Japan Oil Chemists' Society, Online. (https://jocs.jp/en/conference-meeting/)

April 30–May 3, 2023. AOCS Annual Meeting & Expo, Colorado Convention Center, Denver, Colorado, USA.

For in-depth details on these and other upcoming meetings, visit http://aocs.org/meetings or contact the AOCS Meetings Department (email: meetings@aocs.org; phone: +1 217-693-4831).

Kiverdi, a company in Pleasanton, California, USA (https://www.kiverdi.com) is exploring an alternative to palm oil through a process that directly captures carbon dioxide from the atmosphere. The company is also using directed evolution, which applies stress to yeast colonies to spur them to produce more oil from cheaper feedstocks. According to the company, this approach is advantageous because it will avoid the regulations that govern genetically-modified organisms used by other companies in bio oil production. Kiverdi aims to produce yeast strains that are not only highly productive but also more robust.

The Wisconsin, USA-based company, Xylome (https://www.xylome.com), has leveraged yeast fermentation to produce the bio oil, 'Yoil.' The process uses a genetically-modified strain of yeast, *Lipomyces starkeyi*, which are fed corn syrup. The process yields bio oil that has the same chemical profile as palm oil.

In a 2022 *Fast Company* article (https://tinyurl.com/29hyynyj), the company's CEO, Thomas Kelleher, noted that Yoil can be used as a one-to-one drop-in replacement for palm oil. Yoil has another benefit. Unlike palm oil, Yoil does not require bleaching, which removes chlorinated hydrocarbons from the production process and ultimately the food chain. Xylome is sharing samples of Yoil with companies to see how it stands up to traditional palm oil in products like ice cream. The company is also looking into alternative approaches that use waste feedstock from cornfields to make a similar, but less expensive, bio oil product.

Each company faces the same hurdle—scaling production at a price that is profitable. To accomplish this feat, they are optimizing their processes by improving strains, enhancing fermentation efficiencies, identifying the best, most cost-effective and environmentally-sustainable feedstocks, and obtaining additional byproducts from the fermentation stream to improve profitability.

The future of palm oil lies at the intersection of sustainability, agronomic management improvements, and laboratory processes innovations. As more corporations require certification, governments and growers will be motivated to adopt sustainable management practices. Such practices could fold in new research to improve yield and address the immediate need for oil without converting more land for cultivation. Finally, biotechnological advances will improve bio oil characteristics in a cost-effective process that can scale production to augment—if not replace—the demand for palm oil in food and commercial products. The end results may soon be on your supermarket shelves. Stay tuned.

Stacy Kish is a freelance science writer. She has worked for 15 years to bring engaging stories about an array of science topics to a general audience. She can be contacted at earthspin.science@gmail.com

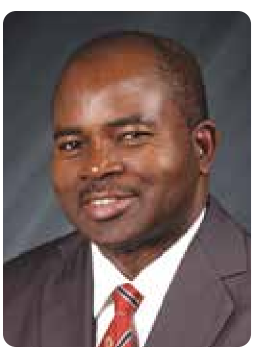
2022 AOCS award recipients

AOCS honors those individuals and institutions who have taken research and technology to the next level, who have advanced the quality and depth of the profession, and who have leveraged their knowledge for the benefit of the Society. Their contributions are critical to AOCS and the advancement of the science and technology of oils, fats, proteins, surfactants, and related materials. We congratulate all the 2022 award recipients!

SOCIETY AWARDS

A. R. BALDWIN DISTINGUISHED SERVICE AWARD

Recognizes an active or previously active member of the Society making outstanding contributions and service to the Society over a substantial period of time. Sponsored by Cargill, Inc.



Casimir is an international authority on the synthesis of structured lipids by enzymatic catalysis who has brought his leadership to many volunteer roles within the Society.

Dr. Casimir C. Akoh is a distinguished research professor at the University of Georgia. He earned a Ph.D. in food science, an M.S. in biochemistry from Washington State University, and a B.Sc. in biochemistry from the University of Nigeria.

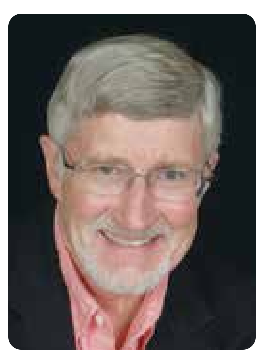
He served on the AOCS Governing Board as secretary, vice president, and president (2008–2009). He has also served on many committees—including the Recognition Program, Membership Steering, and *INFORM* Editorial Advisory committees—and as an associate editor of the *Journal of the American Oil Chemists' Society*.

Dr. Akoh's research is mainly in lipid chemistry and phytochemicals. He is an internationally recognized expert on low calorie fat substitutes and structured lipids. He edited eight books and his "Food Lipids" book, now in its Fourth Edition (2017), is used worldwide as a textbook for graduate instruction. Dr. Akoh's research has resulted in over 850 publications and presentations, including up to 296 peer-reviewed refereed publications, 50 book chapters, eight edited books, four patents, 313 presentations, and 187 invited presentations. He has received nearly $7.5 million in grants and gifts. He is an editorial board member or associate editor of six journals.

Dr. Akoh received two top research awards from international professional societies in 2012: the Supelco AOCS Research Award, and the Institute of Food Technologists (IFT) Nicholas Appert Award. Dr. Akoh has received seven awards or honors from IFT and six from AOCS. He recently received the University of Nigeria Alumni Achievement Award (2015), the IFT Babcock-Hart Award (2018) for food technology contributions that resulted in improved public health through nutrition or a more nutritious food, and the AOCS Alton E. Bailey Award (2019). He is a fellow of IFT, AOCS, ACS, and ISBAB.

AOCS AWARD OF MERIT

Recognizes an AOCS Member who has displayed leadership in administrative activities, meritorious service on AOCS committees, or performed an outstanding activity or service.



Robert's high caliber of leadership and service during his AOCS volunteer roles enhanced the prestige and standing of the Society.

Dr. Robert A. Moreau grew up in Massachusetts and received a B.A. from Boston University and Ph.D. from the University of South Carolina. He also received a postdoctoral fellowship from the University of California at Davis.

Dr. Moreau was a member of the AOCS Governing Board for nearly 13 years, served as chair of the Publications Steering Committee, and participated in numerous other committees. He also served as associate editor, contributing editor, and member of the Editorial Advisory Committee for *INFORM* magazine, and as an associate editor of *Lipids*.

He was instrumental in leading AOCS journals into the modern era by transitioning them to a commercial publisher.

This step has helped the journals remain leading publications in their areas.

Likewise, he helped guide *INFORM* magazine as it transitioned from a publishing outlet for original research to a trade magazine. The magazine continues to be a timely source of information about critical issues and research news.

For 38 years, Dr. Moreau conducted research at the Eastern Regional Research Center, United States Department of Agriculture (USDA), Agricultural Research Service (ARS), in Wyndmoor, Pennsylvania. His research was mainly focused on the analysis of health-promoting lipids (phytosterols, tocopherols, tocotrienols, and carotenoids) in plant oils and other plant materials. He published more than 172 peer-reviewed scientific research publications, of which 33 appeared in either *Lipids* or the *Journal of the American Oil Chemists' Society*.

Dr. Moreau was named an AOCS Fellow in 2009. He received the Herbert J. Dutton Award in 2006, Alton E. Bailey Award in 2015, and A.R. Baldwin Distinguished Service Award in 2021. He has been blessed with a wonderful wife, three great kids and three wonderful grandkids.

Lianzhou played a key leadership role in the formation and growth of the AOCS China Section, bringing new members and international perspectives into the Society.

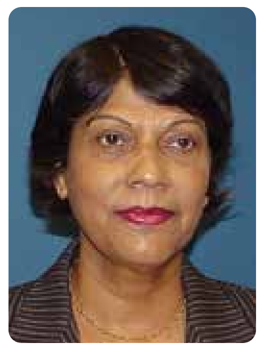
Dr. Lianzhou Jiang is a professor at Northeast Agricultural University (NEAU), China, and fellow of the International Academy of Food Science and Technology.

He led the formation and chaired the AOCS China Section in 2016. He was selected as a valid candidate for the academician of the Chinese Academy of Engineering (CAE) in 2019. Dr. Jiang served as the dean of the College of Food Science at the NEAU, the director of the National Research Center of Soybean Engineering and Technology from 2005–2019. He also served as the committee member of the discipline evaluation group of the State Council of the People's Republic of China, and vice president of the China Soybean Industry Association.

For nearly 40 years, Dr. Jiang has been dedicated to the research of soybean processing theory and technology as well as the cultivation of talents, pioneering the theory of flexible processing of plant proteins, and promoting the creation of a distinctive modern soybean processing industry technology system. He has served on, and chaired, more than 50 scientific and technological projects, including the United Nations Development Programme (UNDP), the National High-tech R&D Program of China ("863" Program), the National Science and Technology Support Program, and the National Nature Science Foundation of China. He has contributed to more than 400 peer-reviewed articles and edited 15 books. He has received more than 30 science and technology awards and obtained nearly 100 authorized invention patents. His research results have been widely promoted and applied, creating tens of billions of yuan of economic benefits and effectively promoting the scientific and technological progress of the global soybean industry.

AOCS FELLOW AWARD

Recognizes achievements in science or extraordinary service to the Society.



Navam has contributed scientific achievements in peptide structure-function research that have increased the global capacity to produce new and novel therapeutic molecules with efficacy against various diseases.

Dr. Navam Hettiarachchy is a professor in the Department of Food Science at the University of Arkansas. She earned a B.S. in chemistry from the University of Madras, India, an M.S. in biochemistry, University of Edinburgh Medical School, Scotland, and a Ph.D. in biochemistry from the University of Hull, England, U.K. She is internationally recognized for her research in maximizing the use of oilseed crops, particularly soy, and rice.

Dr. Hettiarachchy served as chair of the Protein and Co-Products Division as well as moderator and chair of numerous technical sessions at the AOCS Annual Meeting & Expo. In her role as chair, she recruited world-class speakers. She collaborated with other AOCS Divisions to host technical sessions that attracted numerous attendees.

Dr. Hettiarachchy has published 164 journal articles and chapters, in which she provided innovative and creative approaches in fundamental protein chemistry. She pioneered work revealing the structural requirements necessary for peptides to inhibit cancer cell proliferation.

In 1999, Dr. Hettiarachchy and her co-authors received the ADM Award for Best Paper in Protein and Co-Products in the category of Chemistry/Nutrition from AOCS for their article "Hydrophobicity, Solubility, and Emulsifying Properties of Soy Protein Peptides Prepared by Papain Modification and Ultrafiltration." She is a fellow of IFT and the International Union of Food Science and Technology. She has been inducted into the National Academy of Inventors (2015) and won the Spitze Land-Grant Professorial Career Excellence Award for excellence in teaching, research, and service.

In addition to her research, she has developed and taught six outcome-based courses. Her mentorship in product development, IFT College Bowl competition, and others led to student cash awards amounting to $98,550.

Charlotte is one of the leading scientists in developing antioxidant technologies for the use of omega-3 oils in foods.

Dr. Charlotte Jacobsen is a professor and leader of the Research Group for Bioactives—Analysis and Applications at the National Food Institute, Technical University of Denmark. She is internationally renowned for her research in lipid oxidation of omega-3 rich foods.

She has served on the AOCS European Section Leadership Team as president and vice president. As chair of the Lipid Oxidation and Quality Division, Dr. Jacobsen fostered a collaborative and supportive culture for students, academics, and industry professionals. She also served as an associate editor of the *Journal of the American Oil Chemists' Society* and is a member of the AOCS Journal Advisory Board.

She was appointed by European Food Safety Authority as an expert in the Fish Oil Working Group under the Biohazard Panel to evaluate the potential hazards associated with human intake of refined fish oil. Her recent research also concerns the use of side-streams from plant and marine food production as new ingredients (*e.g.*, antioxidants) for the food industry. She has led several large national and international projects, including the on-going EU BBI JU project WaSeaBi. Most of her projects involve collaboration with industry partners, such as Royal Greenland, Kalsec, Nestlé, and Novozymes. Dr. Jacobsen has over 200 publications and 6,500 citations. She has authored 31 book chapters, co-edited four books, and has one granted patent and four pending.

Dr. Jacobsen has received several awards, including the Danish Danisco prize (2003), the French La Médaille Chevreul (2010) awarded by Association Francaise pour l'Étude des Corps Gras, the German DGF Normann Medaille (2020), AOCS Stephen S. Chang award (2021), and two best paper awards from AOCS.

Janitha has contributed significantly to the scientific knowledge of food protein chemistry as well as to the training of future leaders in the oilseed industry.

Dr. Janitha P. D. Wanasundara is a senior research scientist with Agriculture and Agri-Food Canada (AAFC). Her research program is in protein chemistry and bioproducts focusing on oilseeds and pulses produced in Canadian prairies. She has a B.Sc. (agriculture with honors, 1986), a M.Phil (food science and technology) from the University of Peradeniya, Sri Lanka, and an M.Sc. and Ph.D. in food science (1996) from Memorial University, Canada.

As a member of the Protein and Co-Products Division, she established a Lifetime Achievement Award for the Division and streamlined its student poster competition and awards, which increased student participation. In 2019, Dr. Wanasundara helped to establish the AOCS Pulse Science and Technology Forum, serving as a steering committee member. She contributed to program development, as well as organized and chaired sessions. This forum, now called the Sustainable Protein Forum, continues to gather leaders from a wide range of food science applications. She also served as co-editor of a special issue of the *Journal of the American Oil Chemists' Society* on satisfying protein demand through plant and alternative proteins.

Dr. Wanasundara's research furthers understanding of the relationship between a seed protein's genetics and its structure, function, and physical properties. Her research also identifies the macromolecular function of these proteins when used in complex food systems. In the area of plant protein chemistry, her research focuses on understanding the chemistry and structure of seed storage proteins for legumes and dicot crops of *Brassica* to improve application in the plant protein industry.

Her scholarly contributions include 59 peer-reviewed journal articles and 25 book chapters, nearly 100 presentations, one book, and one patent.

Jill is an excellent scientist and highly skilled leader whose service to AOCS has benefited all members of the Society.

Dr. Jill K. Winkler-Moser is a research chemist and lead scientist at the USDA, ARS, in the Functional Foods Research Unit in Peoria, Illinois. She received a B.S. and an M.S. in food science from the University of Idaho and a Ph.D. in food science and human nutrition at the University of Illinois at Urbana–Champaign. She is an authority on lipid oxidation and the chemical and phytochemical characterization of plant and seed oils. Her research has facilitated the development of oils with altered tocopherol compositions for increased oxidative stability.

She has served in several leadership roles with AOCS. She was on the AOCS Governing Board from 2019 to 2021. She also served as chair, vice-chair, and secretary-treasurer for the Lipid Oxidation and Quality Division. As part of Division leadership, she coordinated well-attended events that connected members across the Society. She has demonstrated a long-standing commitment to the *Journal of the American Oil Chemists' Society*, where she has served as associate editor and is currently a senior associate editor. She also served as chair of the Division Council from 2018 to 2020.

Her research has supported the development of new CODEX standards for oils, such as rice bran oil. She also developed a novel and simple method using tocopherol fingerprinting to detect adulteration of coffee by less valuable cereals. Dr. Winkler-Moser has published more than sixty peer-reviewed journal articles. In 2018, Dr. Winkler-Moser and co-authors won the AOCS Edwin N. Frankel Best Paper in Lipid Oxidation and Quality for their article "Application of Differential Pulse Voltammetry to Determine the Efficiency of Stripping Tocopherols from Commercial Fish Oil."

SCIENTIFIC AWARDS

ALTON E. BAILEY AWARD

Recognizes outstanding research and exceptional service in the field of lipids and associated products. Sponsored by ADM.

Keshun is an internationally recognized scholar for his contributions to the chemistry of soybeans, grains, and legumes and sustained advocacy of science in AOCS and other professional societies.

Dr. Keshun Liu is a research chemist with USDA, ARS. Born in rural China, he received a Ph.D. in food science from Michigan State University, and did post-doctoral work at Coca-Cola Co. and University of Georgia. Before joining USDA in 2005, he was an employee at Monsanto Co. and University of Missouri-Columbia. He has been active with AOCS by organizing meeting symposia and contributing his time and knowledge in many other volunteer and committee roles. He served the Proteins and Co-Products Division at all levels of Division leadership.

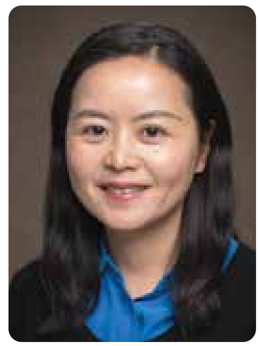
Dr. Liu is well known for his expertise in chemistry, processing, and utilization of soybeans, cereals, and legumes. His seminal research has had significant impacts on food and feed industries and scientific communities. His books on soybeans have become a must-read for researchers in the soy industry; the fibrous meat analog he and colleagues developed at University of Missouri has been commercialized by Beyond Meat. His research on fuel ethanol co-products and their recovery benefits the biofuel industry. Dr. Liu authored or co-authored 139 publications.

His improved analytical methods have been used by laboratories around the world. In January 2021, his trypsin inhibitor assay was approved as AOCS Official Method Ba 12a-2020. His low-cost method for making soy protein concentrates is being evaluated by the Soybean Innovation Lab (University of Illinois at Urbana–Champaign) for use in fighting protein shortage in Africa.

Dr. Liu was named an AOCS Fellow in 2011. He was awarded the Award of Merit in 2010 and Protein and Co-Products Division Lifetime Achievement Award in 2020.

AOCS YOUNG SCIENTIST RESEARCH AWARD

Recognizes a young scientist who has made a significant and substantial research contribution in one of the areas represented by AOCS Divisions. Sponsored by the International Food Science Centre A/S.



Jiajia is an extraordinary scientist, mentor and instructor, who has developed an incredibly strong research program in protein functionality and lipid encapsulation systems.

Dr. Jiajia Rao is an assistant professor in the Cereal and Food Science Program in the Department of Plant Sciences at North Dakota State University (NDSU). She received her B.S. from Sichuan University of Science and Engineering, China (2002), M.S. from Chongqing University, China (2005), and Ph.D. from the University of Massachusetts, Amherst in 2013.

Dr. Rao has worked with the AOCS Protein and Co-Products Division to develop and chair technical sessions on plant proteins. She and her students have presented their latest research at AOCS meetings, helping to amplify this topic within and outside the Society. Her efforts help ensure that AOCS attracts new members as the "go-to" society for new plant protein technologies. She won the AOCS Honored Student Award in 2012.

Dr. Rao worked for PepsiCo Inc. for 3 years, where she was involved in emulsion technology and protein fortified beverage development. At NDSU, her research focuses on the structure and function relationships of plant-based ingredients for improved quality and safety in food. Dr. Rao has published more than 70 peer-reviewed articles. Her research has been supported by grants from the United States Department of Agriculture, food industry and local commodity groups, and she has secured funding worth over $1 million as a principal investigator while working at NDSU since 2015. This funding has enabled Dr. Rao to build up an active and competitive laboratory. She has trained 10 graduate students, 6 post-doctoral appointees, and 4 visiting scientists.

2023 Awards open June 1, 2022!

Start planning your nomination or application now—visit @home or aocs.org/awards to learn more about all the awards AOCS offers.

STEPHEN S. CHANG AWARD

Recognizes a scientist, technologist, or engineer who has made decisive accomplishments in research for the improvement or development of products related to lipids. Provided by the Stephen and Lucy Chang endowed fund.

Xavier is a pioneer in enzyme-based technology and a true leader in his field.

Dr. F. Xavier Malcata is a professor in the Department of Chemical Engineering of University of Porto and senior researcher at the Laboratory for Process Engineering, Environment, Biotechnology and Energy. He received his Ph.D. (1991) from the University of Wisconsin–Madison.

His research on lipases in immobilized form has supported a number of industrial advances. Dr. Malcata's various reviews on the subject have become classical references for anyone interested in enzymes for catalytic reactions of hydrolysis, ester synthesis, acidolysis, alcoholysis, or transesterification. He pioneered immobilization of lipases for modifying oils and fats via hydrolysis and transesterification and developed non-conventional configurations of photobioreactors for producing polyunsaturated fats and high-added value metabolites by lipidogenic microalgae.

He has authored 470+ refereed papers that have received more than 17,500 cites by peers, with an h-index of 65. He currently appears in the 0.5%-top tier of Stanford University ranking of the most influential researchers worldwide.

He has also edited 5 books and published 17 books, including the 11-volume treatise titled *Enzyme Reactor Engineering* published by Wiley, and the 3-volume collection titled *Food Process Engineering* published by CRC. In addition, he has supervised 30 Ph.D. dissertations, coordinated 37 research and development projects, and written 55 book chapters.

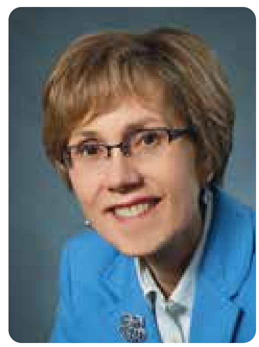
Dr. Malcata is the recipient of many prestigious awards, including the Ralph H. Potts Memorial Award (1991) and Young Scientist Research Award (2001) from AOCS; Foundation Scholar Award (1998), Danisco International Dairy Science Award (2007), Distinguished Service Award (2012) and Teaching Award in Dairy Manufacturing (2019) from the American Dairy Science Association; Samuel Cate Prescott Award (2008) and William V. Cruess Award (2014) from IFT; and International Leadership Award (2008) and Elmer Marth Educator Award (2011) by International Association for Food Protection. He was named an AOCS Fellow in 2014.

Laboratory Proficiency Program Awards

AOCS' Laboratory Proficiency Program is the world's most extensive and respected collaborative proficiency program for oil- and fat-related commodities, oilseeds, oilseed meals, and edible fats. A full listing of the Laboratory Program winners is available on aocs.org/series.

SUPELCO AOCS RESEARCH AWARD

Recognizes outstanding original research in fats, oils, lipid chemistry, or biochemistry. Sponsored by MilliporeSigma.



Penny is a world class lipid chemist contributing cutting-edge research in the areas of dietary fats, coronary heart disease, and human nutrition.

Dr. Penny M. Kris-Etherton is the Evan Pugh University Professor of Nutritional Sciences in the Department of Nutritional Sciences at The Pennsylvania State University, where she has served on the faculty since 1979. She earned her B.S. from the Rochester Institute of Technology, M.S. from Case Western Reserve University, and Ph.D. from University of Minnesota.

Her clinical nutrition research focuses on understanding the effect of diet on cardiovascular disease (CVD) risk factors. Dr. Kris-Etherton has served on committees that have issued dietary guidelines (the 2005 Dietary Guidelines for Americans Advisory Committee and the 2002 National Academies Dietary Reference Intakes for Energy, Macronutrients and Cholesterol). She served on the second Adult Treatment Panel of the National Cholesterol Education Program.

Dr. Kris-Etherton has co-authored numerous American Heart Association (AHA) Scientific Statements and Advisories that have made lifestyle recommendations for the prevention and treatment of CVD. She also co-authored the National Lipid Association's recommendations for Patient-Centered Management of Dyslipidemia. In addition, she served on the American College of Cardiology Expert Consensus Decision Panel that published a paper on the management of ASCVD risk reduction in patients with persistent hypertriglyceridemia.

Dr. Kris-Etherton is a former chair of both the AHA Council on Lifestyle and Cardiometabolic Health and the AHA Nutrition Committee. She is a Fellow of the AHA, the National Lipid Association (where she was president), and the American Society for Nutrition. She has published over 420 papers and has received numerous awards from the American Society for Nutrition, AOCS, Academy of Nutrition and Dietetics, International Nut & Dried Fruit Council, and National Lipid Association for her scientific contributions.

In 2014, she received the AOCS Ralph Holman Lifetime Achievement Award.


Holčapek

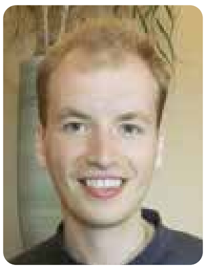

Green


Ju


Chen


Guo

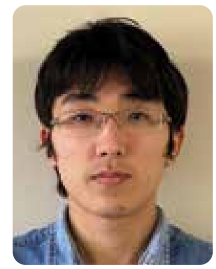

Herrera

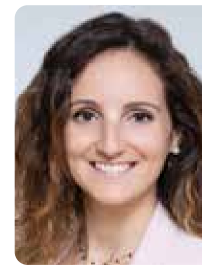

Klooster


Dhavamani


Belury


Baba


Chida


Canelli

DIVISION AWARDS

ANALYTICAL

Herbert J. Dutton Award
Michal Holčapek, University of Pardubice, Czech Republic

Student Award
Hilary Green, University of California, Davis, USA

BIOTECHNOLOGY

Ching Hou Biotechnology Award
Lu-Kwang Ju, The University of Akron, USA

Student Award
First place:
Jiazi Chen, Jinan University, China

Second place:
Xin Guo, University of Massachusetts, Amherst, USA

EDIBLE APPLICATIONS TECHNOLOGY

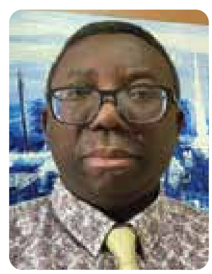
Timothy L. Mounts Award
Maria Lidia Herrera, University of Buenos Aires and National Research Council of Argentina (CONICET), Argentina

Student Award
Sten ten Klooster, Wageningen University, The Netherlands

HEALTH AND NUTRITION

New Investigator Research Award
Sugasini Dhavamani, University of Illinois at Chicago, USA

Ralph Holman Lifetime Achievement Award
Martha Ann Belury, Ohio State University, USA


Aluko


Varanasi

Student Award
Waqas Baba, United Arab Emirates University, United Arab Emirates

INDUSTRIAL OIL PRODUCTS

Student Award
Tsutomu Chida, Tohoku University, Japan

PROCESSING

Student Award
Greta Canelli, ETH Zürich, Switzerland

PROTEIN AND CO-PRODUCTS

Lifetime Achievement Award
Rotimi E. Aluko, University of Manitoba, Canada

SURFACTANTS AND DETERGENTS

Samuel Rosen Memorial Award
Padma Prabodh Varanasi, BASF, USA

STUDENT AWARDS

HANS KAUNITZ AWARD
Morgan Kandrac, Rutgers University, USA

LIPID CHEMISTRY AND NUTRITION AWARD
Sponsored by Seawit Co.
H. M. A. Ruchira Nandasiri, University of Manitoba, Canada

AOCS FOUNDATION
Manuchehr (Manny) Eijadi Award
Lingyi Liu, University of Nebraska-Lincoln, USA

Honored Student Award
Snigdha Guha, University of Nebraska-Lincoln, USA
Lingyi Liu, University of Nebraska-Lincoln, USA
Han Peng, Memorial University of Newfoundland, Canada

Peter and Clare Kalustian Award
Snigdha Guha, University of Nebraska-Lincoln, USA

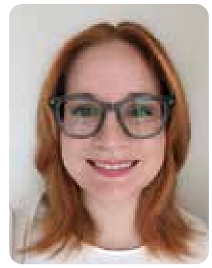
Thomas H. Smouse Memorial Fellowship
Melissa A. Marsh, Utah State University, USA

BEST PAPER AWARDS

AMERICAN CLEANING INSTITUTE (ACI) DISTINGUISHED PAPER AWARD
Sponsored by American Cleaning Institute (ACI).
Interactions of Surfactants with Biomimetic Membranes. 1. Ionic Surfactants (JSD 24(4):661–667).
Nikolai Kocherginsky and Brajendra K. Sharma

2022 AWARD SPONSORS
AOCS thanks all award sponsors for their generous support. Sponsors make it possible for AOCS to recognize outstanding scientists, researchers, technicians, and students within our community.

American Cleaning Institute (ACI)
AOCS Foundation
ADM
Archer Daniels Midland Foundation
Cargill Inc.
Stephen S. and Lucy D. Chang
Manuchehr (Manny) Eijadi
International Food Science Centre A/S
International Lecithin and Phospholipid Society
Kalsec Inc.
Peter and Clare Kalustian Estate
MilliporeSigma
Milton J. Rosen
Seawit Co.
Vijai K. S. Shukla
Thomas H. Smouse and Family


Kandrac


Nandasiri

Liu


Guha


Peng


Marsh

ADM AWARD FOR BEST PAPER IN PROTEIN AND CO-PRODUCTS
Sponsored by ADM.
Chemistry/Nutrition Category
An International Collaborative Study on Trypsin Inhibitor Assay for Legumes, Cereals, and Related Products
(*JAOCS 98* (4):375–390).
Keshun Liu, Susan Seegers, Wenming Cao, Janitha Wanasundara, Juxing Chen, Alessandro Esteves da Silva, Kristopher Ross, Alexandra Lozano Franco, Theo Vrijenhoek, Pankaj Bhowmik, Yonghui Li, Xin Wu and Scott Bloomer

Engineering/Technology Category
Effect of Peroxyl-Radicals-Induced Oxidative Modification in the Physicochemical and Emulsifying Properties of Walnut Protein (*JAOCS 98*(9):903–910).
Xiaoying Mao, Dandan Wang, Lingge Sun, Jian Zhang and Qingzhi Wu

EDWIN N. FRANKEL AWARD FOR BEST PAPER IN LIPID OXIDATION AND QUALITY
Sponsored by Kalsec, Inc.
Quantitative Evaluation of Oxidative Stability of Biomembrane Lipids in the Presence of Vitamin E
(*JAOCS 98*(5):567–579).
Atsushi Takahashi, Ryota Takahashi, Kousuke Hiromori, and Naomi Shibasaki-Kitakawa

PHOSPHOLIPID DIVISION BEST PAPER AWARD
Sponsored by International Lecithin and Phospholipid Society (ILPS).
Dietary lysophospholipids reduce lymphatic cholesterol transport compared with dietary phospholipids in thoracic lymph-duct cannulated rats (*Lipids 56*(6):579–590).
Ai Takeyama, Asami Teramoto, Tianyu Wang, Takuya Hayashi, Yasutake Tanaka, Masao Sato and Bungo Shirouchi


Save the date!
Sustainable Protein Forum
October 4–6, 2022
Chicago, Illinois, USA | Online
Join thought leaders in sustainable food proteins to explore advances in structure function relationships, fermentation, cellular technologies and food product design as we chart the course to sustainable nutrition together.
Three days of stimulating discussion and networking, seamlessly integrated live and online.
sustainableprotein.aocs.org
AOCS

Assessing a recent report on the association between palm oil and cancer metastasis

Elaine S. Krul

Concerns about cancer risk from consuming palm oil started appearing in the lay press in 2016. A report published by the European Food Safety Authority (EFSA) at the time stoked fear about the prevalence of free and esterified 3- and 2-monochloropropane-1, 2-diol (MCPD) and glycidol in edible oils. Unesterified and esterified forms of the glycerol-based compounds fed at high doses to rats or mice were reported to lead to deleterious health effects, with glycidol being considered a carcinogen.

- No substantive scientific evidence supports concerns about cancer risk from palm oil consumption, yet the press continues to insinuate an association.
- A study published in late 2021, again raised concerns that palm oil consumption could promote cancer metastases, but the experimental design clouds any clear conclusions.
- A number of scientific panels have recently concluded that normal levels of palm oil consumption pose no safety risks for infants and adults alike.

FIG. 1. Joe Schwarcz, director of the Science and Society Office at McGill University in Montreal, Canada, discusses the media response to the paper by Pascual *et al.* on his YouTube channel – The Right Chemistry.
Source: https://www.youtube.com/watch?v=-B-caDurxGs

Glycerol-based contaminants in foods are predominantly present bound to fatty acid esters and are, therefore, identified as 3-monochloropropane-1,2-diol esters (3-MCPDE) and glycidyl esters (GE). These compounds can be generated through: hydrochloric acid hydrolyses of proteinaceous oilseeds, during high temperature and high pressure edible oil refining, and while cooking or baking food. The EFSA report listed

refined palm oil as having the highest relative concentrations of 3-MCPDE and GE, but they are also found in other refined vegetable oils and refined fish oils.

Subsequent reports published from two symposia—one by the Nutrition Foundation of Italy (May, 2016) and one by a team of Spanish experts in food industry, nutrition, toxicology, sustainability, and veterinary science (Madrid, July 2018)—were consistent in finding "no effect of palm oil consumption on human health (and specifically on CVD or cancer risk)" can be foreseen and "no evidence associating PO consumption and higher cancer risk, incidence or mortality in humans."

In 2020, The European Commission set standards for the maximum allowable concentrations of 3-MCPDE and GE in foods based on the findings in the EFSA report (https://doi.org/10.2903/j.efsa.2016.4426). The CODEX Committee on Contaminants in Foods also generated a draft Code of Practice (COP) for the Reduction of 3- MCPDE and GE in Refined Oils and Food Products in 2019 (https://tinyurl.com/5xhs35d9). EFSA recognized that the food industry has made significant progress to mitigate the formation of these glycerol-based contaminants and reduce consumer exposure.

Nonetheless, once again media attention has turned to a laboratory reporting the possibility that palm oil, and specifically palmitic acid (PA), increases cancer's spread in the body (https://doi.org/10.1038/s41586-021-04075-0). In the most recent report published online in December 2021, the authors of one laboratory noted that human cancer cells exposed to PA *in vitro* had a higher degree of metastases (or grew and spread more) compared to cells exposed *in vitro* to oleic or linoleic acid. In addition, when human oral squamous carcinoma or skin melanoma cells were implanted in mice fed a high palm oil diet the researchers observed more metastases in secondary mice implanted with these cells versus cells from mice fed a control diet.

As a result of the commotion generated by this report (including an active thread on AOCS inform|connect), the European Food Information Council (EUFIC) issued a public statement (https://tinyurl.com/2p8drdh5) that the study

TABLE 1. Fraction of palmitic acid, represented as a percentage of the total fatty acids, commonly found in a variety of food sources. Source: *J. Dairy Sci. 90*:2596–2603, 2007, *J. Dairy Sci. 94* :59–65, 2011, *Front. Physiol. 8*: 902, 2017, *Meat Musc. Biol. 5*, 34: 1-16, 2021 and Fatty Acid and Lipid Chemistry. Springer, Boston, MA, 1996.

Food	Average % of total fatty acid as PA
Butter	27-32
Lard	27
Palm oil	44
Bovine milk	28
Cocoa butter	26
Beef muscle	23-31
Soybean oil	15
Peanut oil	13
Corn oil	13
Olive oil	8-20

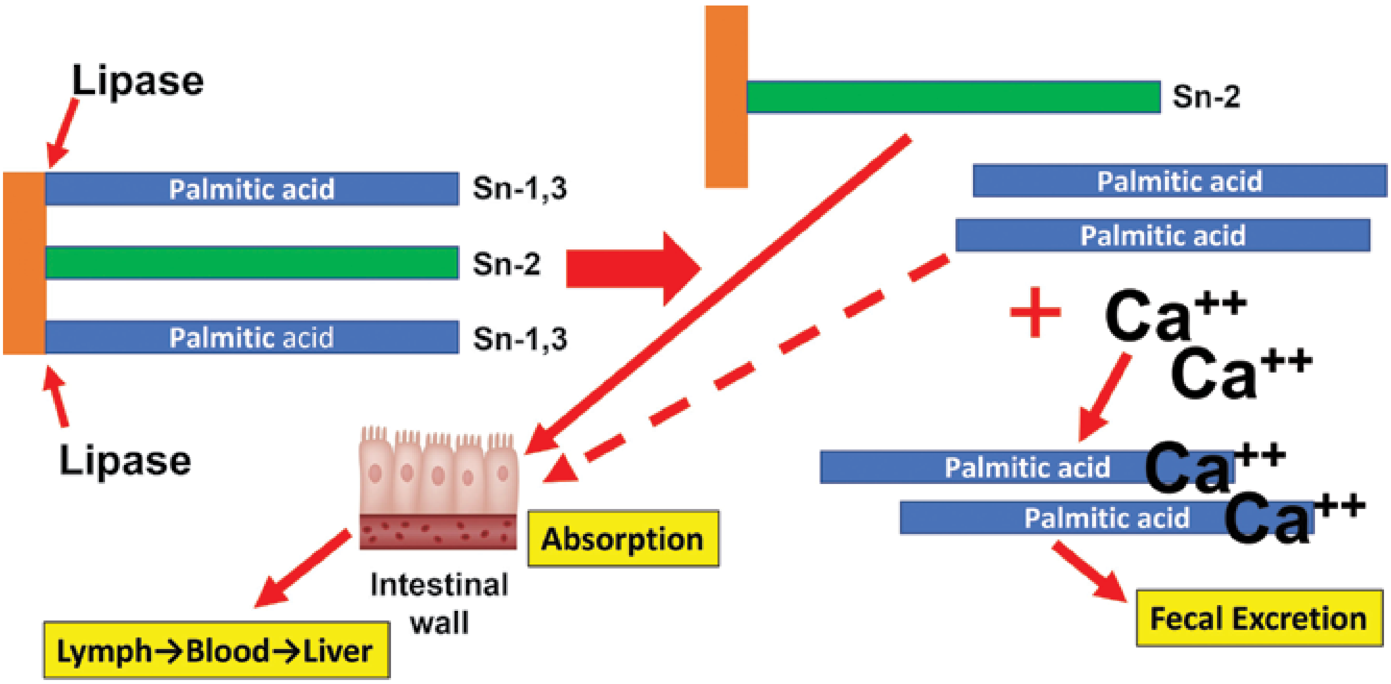


FIG. 2. Metabolic fate of dietary fatty acids differs depending on position in triglycerides Source: Adapted from Marangoni F. *et al.*, *Int. J. Food. Sci. Nutr.*, *68*: 643–655, 2017.

should be viewed in context, listing a number of points that need to be considered to avoid making inaccurate conclusions. This article will raise additional points in more detail, but first, it behooves the reader to have a basic understanding of the biological role of PA in the body in order to knowledgeably interpret this and other studies.

PALMITIC ACID IN THE BODY

Palmitic acid (16:0) (PA) is the most common saturated fatty acid (SFA) in the human body, comprising 20–30% of the total fatty acids (FA) in membrane phospholipids (PL) and adipose triacylglycerols (TAG). It accounts for 45-50% of the total fatty acids in the fetus and 20-30% of total fat in human breast milk.

Despite varying levels of intake, the concentrations of PA in body tissues do not vary much under normal conditions. Endogenous PA is synthesized through *de novo* lipogenesis from other fatty acids, carbohydrates, or amino acids. When excess PA exists, it is desaturated to palmitoleic acid (16:1n–7, POA) and/or elongated to stearic acid (16:0) (SA) and then further desaturated to oleic acid (18:1, OA) by delta-9 desaturase.

A myriad of biological functions rely on PA. It plays an important role in maintaining cell membrane composition which is essential for cell division and membrane trafficking. It is a major component of lung surfactant. PA modulates the function of different proteins through palmitoylation and ~~as~~ a precursor to palmitoylethanolamide (PEA) which has anti-neu-

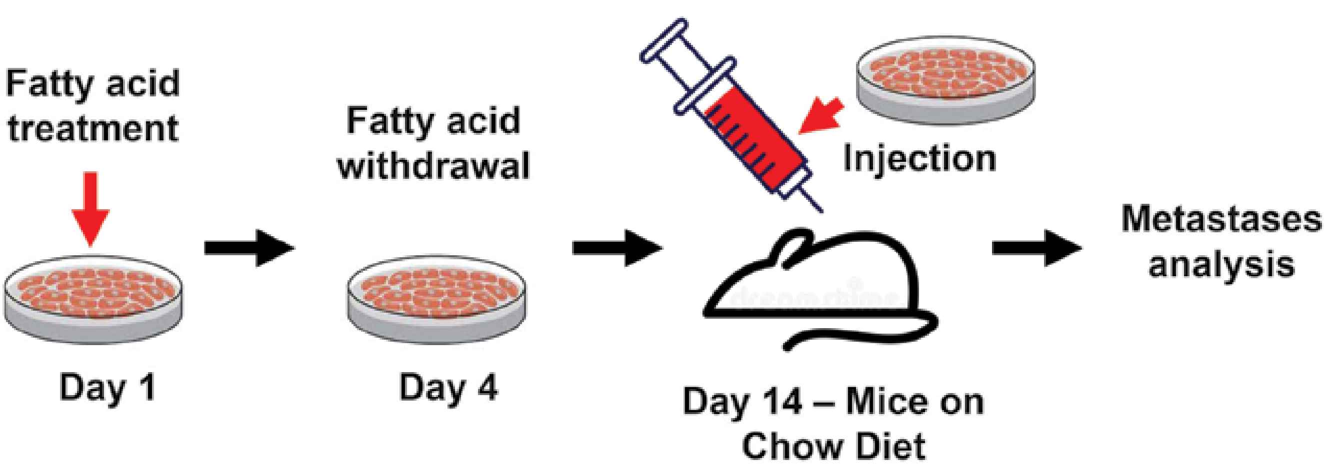


FIG. 3. Design of experiments using in vitro exposure of cancer cells to fatty acids prior to injection into mice. Source: Adapted from Pascual *et al.*, *Nature*, *599*: 485-490, 2021.

roinflammatory and analgesic properties (https://doi/10.3389/fphys.2017.00902).

Daily intake for PA averages between 20-30 grams per day and it is commonly found in a variety of food sources (Table 1). Dietary guidance from the American Heart Association and WHO/FAO recommends limiting intakes of SFA to <10% of total daily energy, since high SFA diets are associated with an increased risk of atherosclerotic cardiovascular disease by elevating plasma low-density lipoprotein cholesterol (LDL) concentrations. However, research now indicates that the food matrix significantly affects the potential of SFA to impact LDL and other risk factors.

The stereospecificity of the fatty acids of triacylglycerol (TAG) present in food are a good example of the food matrix effect. The sn-1 and sn-3 fatty acids in dietary TAG are hydrolyzed by pancreatic lipase releasing 2-monoacylglycerols (2-MAG). SFA released as fatty acids in the gut tend to form insoluble calcium soaps that are not well absorbed, while the 2-MAG are absorbed directly by diffusion into the intestinal cells (Fig. 2).

Breast milk TAG contains predominantly PA in the sn-2 position which ensures good absorption of PA by the infant which is optimal for normal growth. On the other hand, PA in the sn-2 position in foods intended for adults contributes to excess SFA absorption if such TAGs are overconsumed. Liquid palm oil has 89-100% of sn-2 positions occupied by unsaturated fatty acids while lard has over 85% SFA at this position.

Human trials comparing the effect of plasma lipid parameters on people consuming palm oil or monounsaturated oils reiterate other findings on sn-2 positioning. The trials showed that there was no difference in serum cholesterol levels, suggesting good absorption of the unsaturated sn-2 fatty acids in palm oil and a low atherogenic risk (https://doi.org/10.5650/jos.ess18009).

EVALUATING WHETHER PALM SPREADS CANCER

Now to get back to the recent paper by Pascual *et al.* which implicates palmitic acid and palm oil in inducing the growth and spread of oral squamous carcinoma and skin melanoma cells. The overall study demonstrated a high level of technical expertise on the part of the investigators, yet one has to consider the design of the experiments before concluding that the data support the notion that palmitic acid and palm oil promote metastases. Specifically, a number of points bear mentioning that provide more perspective on the authors' conclusions.

Not a good facsimile for the average human

The studies were carried out in severely immunodeficient mice genetically engineered to facilitate research on human cancers. Experiments that evaluated the growth and spread of the human cancer cells employed NSG^{TM} (NOD.*Cg-Prkdc*^{scid}*IL2rg*^{tm1Wjl}*/SzJ*) mice which are immunodeficient permitting the implantation and growth of human cancer cells. This model is very useful for researchers wishing to study potential cancer therapies. However, the observations made after feeding these mice a high fat palm oil diet cannot be directly extrapolated to humans.

Experimental design far from in vivo *reality*

The authors exposed human cancer cells *in vitro* to one fatty acid at a time to evaluate their propensity to stimulate a metastatic phenotype. While this allows the investigators to study single fatty acids, in reality, cells *in vivo* are exposed to multiple fatty acids and other metabolites at any one time.

While some experiments used the same concentrations (50 µM) of unsaturated oleic acid (OA) and linoleic acid (LA) for comparison, many experiments used PA at 300 µM. Using such a high concentration of OA and LA would be toxic to cells. Only one series of experiments evaluated the impact of another saturated fatty acid, stearic acid (50 µM), on inducing a metastatic potential in cells.

Many experiments compared PA-treated cells to untreated cells. While untreated cells serve as a baseline control, it does not allow a comparison of how other fatty acids or metabolites may relate to their findings.

The authors have shown, in this work and previous studies, that the protein coding gene called CD36 drives the growth and spread of cancer cells. Indeed, as most cancer cells use environmental fatty acids as a nutrient source while they increase *de novo* lipogenesis, CD36 expression is key to transporting fatty acids into cells. The investigators noted that CD36 gene expression increased after PA exposure of cells or a high fat PA diet, but no other fatty acids nor high carbohydrate diets were tested as a comparison. The CD36 protein binds to long-chain saturated fatty acids (LCFA) nonspecifically and only low concentrations of LCFA are required for CD36 function. Until more investigators conduct a comparison of PA with other LCFA to determine their influence on CD36 gene expression and receptor function, these researchers cannot conclude that PA uniquely promotes CD36 mediated cancer growth.

Inappropriate comparison of diets

In order to evaluate the role of dietary palmitic acid (as palm oil) in inducing a metastatic phenotype of implanted human cancer cells, the investigators chose to feed mice one of two high fat purified diets (42% kcal from fat): TD150067, a modified Western diet containing palm oil or TD 09820, a high fat olive oil diet. While not provided in the publication, the nutrient profiles of the diets were provided upon request and reveal that the palm oil diet, but not the olive oil diet, contained 0.15% added cholesterol. A proinflammatory milieu results from feeding rodents this level of cholesterol, generating oxidized lipid species that stimulate CD36 function.

Furthermore, many of the experiments reported only compared the palm oil diet to a normal chow diet. The composition of the chow diet was not provided, but chow diets (approx. 12% kcal from fat) are not appropriate control diets to compare with purified high fat diets. Gut microbiota from mice fed chow versus purified diets are drastically different even after only a few days of feeding. The bottom line is that the induction of a metastatic phenotype that the authors observed on the palm oil diet

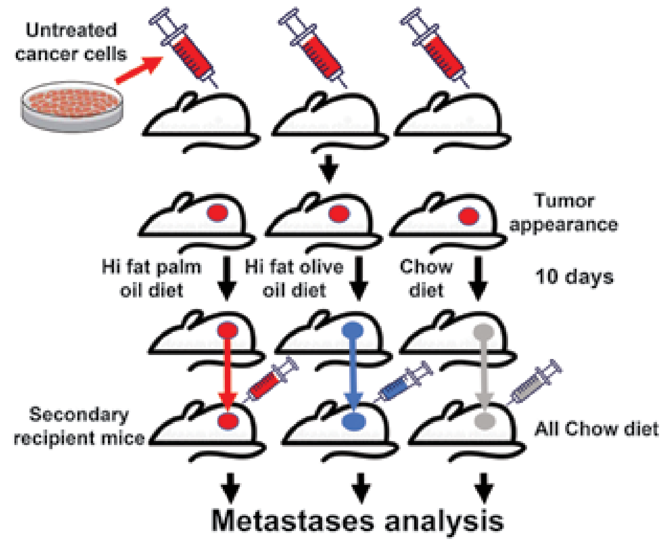


FIG. 4. Design of experiments using in vivo exposure of cancer cells to experimental diets prior to injection into secondary recipient mice Source: Adapted from Pascual *et al.*, *Nature, 599*: 485-490, 2021.

can result from a broad number of factors which cloud any possible attribution to palmitic acid.

In conclusion, no evidence in this study suggests that PA causes cancer. However, under the conditions selected by the authors the data show that PA alone or a high fat palm oil diet containing cholesterol elicited a metastatic profile in human cancer cells. As indicated previously, expert reports emanating from recently held symposia concluded that there was no human data to suggest palm oil consumption or palmitic acid itself is a cancer risk. As palmitic acid is an essential component of breast milk, a recent review by The European Society for Pediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) also concluded that there was insufficient evidence to suggest that palm oil should be avoided as a source of fat in infant formulas for health reasons (https://doi.org/10.1097/MPG.0000000000002307).

The controversy over whether palm oil and palmitic acid consumption results in adverse health effects is likely due to studies where conditions mimic a state of excess PA accumulation in the body, representing a disrupted homeostatic state that normally controls PA tissue concentrations. Overconsumption of SFA or carbohydrates or having a sedentary lifestyle can abnormally increase tissue PA leading to dyslipidemia, hyperglycemia, adipose accumulation, and a pro-inflammatory state. Due to the points raised above, the study by Pascual *et al.* should not raise concerns that normal dietary PA intake promotes cancer metastases.

Elaine S. Krul is president of EKSci LLC and adjunct associate professor at Washington University in St. Louis, Missouri, USA. She has over 40 years of research experience in both academia and industry focusing on lipid and protein metabolism and currently serves as a consultant in nutrition science. She can be contacted at eskrul01@gmail.com

SPONSORED CONTENT

The Story of SOYLEIC

SOYLEIC was an idea created by the farmer for the farmer. Farmers knew there needed to be another avenue for soy oil and with soybeans' rich genetic makeup it was only time before SOYLEIC came to life. A discovery, an evaluation, and a decade of research resulted in one of soybeans' most versatile traits.

In the late 2000s, Grover Shannon, a soybean breeder, and the soybean breeding team at the University of Missouri's Fisher Delta Research Center discovered a non-GMO high oleic trait that stemmed from a traditional cross in the field. Shannon then partnered with a USDA molecular geneticist, Kristin Bilyeu, to evaluate the importance of a non-GMO high oleic trait.

This trait evolved into what is known today as SOYLEIC, a non-GMO, high-oleic soybean trait available now to seed developers that results in high oleic soybean oil and non-GMO meal. This gives farmers the option of growing soybeans for emerging value-added markets.

SOYLEIC was developed through partnerships between the University of Missouri, the U.S. Department of Agriculture, Missouri Soybean Merchandising Council and the United Soybean Board.

"The soy checkoff continually innovates beyond the bushel, and the SOYLEIC high oleic trait is a remarkable example of our investments improving the quality of U.S. soybeans," said Polly Ruhland, United Soybean Board CEO. "These advanced genetics create lasting impacts for soyfoods and industrial uses, and our farmers could not be prouder of what they've accomplished."

The resulting patents for SOYLEIC were licensed to the Missouri Soybean Merchandising Council (MSMC). The MSMC is a farmer run organization dedicated to improving the profitability of the Missouri soybean farmer through a combination of research, promotion, and education.

Led by MSMC and funded through the soy checkoff, several land grant universities and private organizations are working to expand the trait to maturity groups 00 to VII. This will enable production of SOYLEIC broadly across soybean production geographies ranging from as far West as Nebraska, across the North Central states of South Dakota and Minnesota, to the traditional "corn belt" states of the Midwest and over to the East Coast regions of upstate New York, as well as the Southeastern states.

"SOYEIC soybeans are an excellent representation of Missouri Soybeans' checkoff research at work," said Gary Wheeler, Missouri Soybeans CEO and executive director. "Every small item adds up in research, and the checkoff gives us the opportunity to compete, innovate, educate and promote one of the most versatile crops on the planet. It is amazing what one session of trial and error in the field can lead to – SOYLEIC soybeans."

US high oleic soybeans have oil that typically contains 75% or greater oleic acid (Omega-9/monounsaturated fat), less than 3% linolenic acid and 12% or less saturated fats. Typically, soybean oil has a 23% oleic, 8% linolenic acid and 15% saturates content. The improved fatty acid profile provides an oil with superior heat and oxidative stability. This functional advantage is a valuable tool in filling the void created by regulations that require the elimination of trans fats in foods. High oleic beans have comparable oil and protein content to commodity soybeans which produces a soybean meal with the same composition of protein and amino acids.

With these traits, farmers can better meet the needs of food oil, livestock meal, and soyfoods markets. Consumers and food manufacturers are consistently looking for healthy food options that are delicious, nutritious, and affordable.

For the same reasons high oleic soy is excellent in food applications, it is also proving true in non-food markets. Today,

Photos: United Soybean Board

many companies are looking for renewable, bio-based alternatives made from petroleum, and that also provide for better environmental stewardship while maintaining or improving the product's functional properties. High oleic soy's excellent heat and oxidative stability is opening new markets for soybean oil such as industrial lubricants and greases. It is being used to make marine oils, cutting oils, transformer oils, chainsaw and machine lubricants, hydraulic fluids, and railroad greases.

Research recently completed by Iowa State University and the United Soybean Board has resulted in an improved asphalt binding agent that offers an improved and lower cost alternative to the petroleum-based polymers traditionally used. High oleic soy oil makes the polymers have better elastic properties, making it more resilient at high temperatures and resistant to cracking at low temperatures. In addition, it increases the re-use rate on asphalt grindings from 17% to more than 30%.

For the oleochemical industry, high oleic soy offers a rich source of oleic acid, which provides better uniformity in addition to reducing separation costs in comparison to beef tallow. U.S. soybean farmers now have an option to grow SOYLEIC soybeans that can be crushed into high oleic soybean oil and meal. Key benefits of growing SOYLEIC soybeans include potential premiums, diversification of soybean acres, and high end-user demand.

SOYLEIC also meets the functionality and performance needs of food manufacturers and is proving to be a promising non-GMO option for livestock feed.

Today, research is underway with dairy cows, poultry, and hogs. SOYLEIC's fatty acid profile and non-GMO status make it a unique feed ingredient for livestock farmers. Specifically, high oleic soybeans in dairy cow diets may increase milkfat yield.

A recent Penn State Feeding Study compared normal to high oleic extruded and roasted soybeans. High oleic soybeans resulted in 0.17 units high milk fat concentration and 0.2 pounds higher milk fat yield. Additionally, high oleic soybeans improved milkfat composition by increasing heart-healthy monounsaturated (oleic) fat content and decreasing trans fatty acids by 17%.

"Because agronomics and fat and protein concentration are equivalent, there are few downsides to growing or feeding high oleic soybeans," said Kevin Harvatine, professor of nutritional physiology, Penn State College of Agricultural Sciences.

However, growing SOYLEIC high oleic soybeans requires identity preservation, so that end users are confident the product they receive will consistently meet composition specifications. A supply chain that keeps SOYLEIC soybeans separated from commodity soybeans will assure that the value of high oleic oil and non-GMO meal is captured.

In identity-preserved (IP) systems, each value chain participant is responsible for every step in production, from producing seed to commercial soybean production, marketing, crush and end use. IP systems are becoming more commonly used by farmers and the grain industry for specialty crop production which is helping to enable the expanded commercialization of the SOYLEIC trait.

"Consumers are increasingly concerned with knowing what's in their food and where it came from," said Bryan Stobaugh, Missouri Soybeans' director of licensing and commer-

cialization. “The identity-preserved systems that help SOYLEIC deliver performance and functionality also enable full traceability from farm to fork.”

Along with traceability, sustainability standards for food products are increasingly being established by both local companies and Fortune 500 corporations. As a US grown soybean, SOYLEIC is produced under standards consistent with the US Soybean Sustainability Protocol.

In the past 40 years, US soybean farmers have reduced the energy it takes to raise a bushel of soybeans by 35%. American soybean farmers are using tools like precision agriculture to apply fertilizer only where it is needed; they are increasing soil health by minimizing tillage and adding organic matter to their fields; and farmers are increasing the biodiversity on their farms by incorporating protected acres for wildlife and native plants. Additionally, with a longer fry life, SOYLEIC improves oil utilization efficiency in frying applications and reduces the need for oil container packaging and disposal.

“With the growing population around the world, the use of a sustainable crop is pertinent to feed our families, friends, and animals,” said Stobaugh.

U.S. soybean farmers are committed to raising a sustainable product and continuing to improve their practices to minimize the impact on the environment. SOYLEIC soybeans support farmers’ efforts to meet their 2025 goals to reduce land use impact by 10%, lower soil erosion by an additional 25%, increase energy use efficiency by 10% and decrease total greenhouse gas emissions by 10%.

SOYLEIC really is the best of both worlds for both the producer and consumer. The trait aligns with goals set by food companies and the farmer, while pleasing the consumer with functionality and nutritional benefits. As one of the most consumed vegetable oils used in food around the world, improving the quality of soybean oil can have a major positive impact on global consumers. With bans and regulations around trans fats and partially hydrogenated oils, the introduction of high oleic soybean oil is a welcomed addition to the food industry. SOYLEIC provides an ideal, easy to incorporate solution for shortenings without partial hydrogenation, eliminating the presence of trans fats.

Keep in mind, SOYLEIC was not created through gene editing or genetic engineering, making it a true non-GMO option for high oleic soybeans, oil, and meal. While scientists wholeheartedly agree that GMOs are safe for food use and consumption, consumers want to have choices when making food decisions which can create a value capture opportunity for soybean farmers

One of the leading benefits to consumers is SOYLEIC’s heart healthy claim. High oleic soybean oil carries a qualified FDA heart health claim recognizing that it can lower cholesterol and may reduce the risk of coronary heart disease. It also has lower saturated fat and three times the amount of beneficial monounsaturated fatty acids compared to conventional soybean oil contributing to lower blood pressure and cardiovascular health.

Soybean oil is non-allergenic when highly refined—as is common in most food manufacturing applications. Ultimately,

SOYELIC is a functional, sustainable and non-GMO way to eliminate trans fats and provide a high stability healthier oil with an improved flavor profile. A win-win-win, for all players involved.

SOYLEIC has been produced in 14 states across nation and recently became available internationally through the first commercial license in 2021 with Italian multinational company, Sipcam Oxon. This year, SOYLEIC soybeans will be planted in nearly 60,000 across the US.

“With a multi-year acreage growth rate that continues to more than double, SOYLEIC is the fastest growing high oleic seed product in the industry,” said Russ Sanders of Sanders Advisors and consultant to Missouri Soybeans. “By bringing high oleic soybean oil to both domestic and international markets in strong non-GMO seed genetic lines, SOYLEIC provides growers and end users with a way to create and capture value in both high stability oil and non-GMO meal markets.”

The representation of SOYLEIC in the US and export markets proves that when food science and agriculture technologies meet, opportunities flourish. High oleic soybean oil is leading the way in growing U.S. soybean demand today and will be in years to come.

“Bringing novel research to light with the ability to change the demand of soybean oil domestically and internationally is why the SOYLEIC trait is innovative,” said Stobaugh. “It brings down the barriers associated with health claims, brings soybean oil back to human and animal use, creates new demand markets for soybean oil and expands the current high oleic portfolio.”

The research and marketing work does not stop here though. SOYLEIC product and market development efforts are continuously working to increase seed product availability and performance, and open new markets to drive demand.
What started as an idea created by the farmer for the farmer has grown into a versatile product created for the global food industry, for the livestock producer, for the cutting edge seed company, for the local consumer – for all.

To learn more about SOYLEIC please visit soyleic.com.

Nanoemulsions may be part of a greener future in cosmeceuticals

Olio is an Inform *column that highlights research, issues, trends, and technologies of interest to the oils and fats community.*

Alexa Tascher

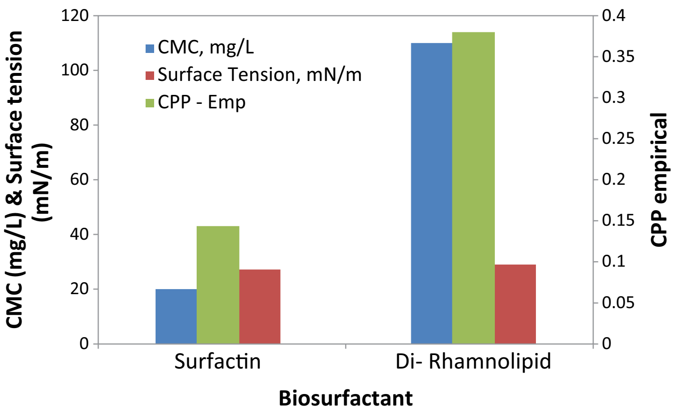
One of the most widespread and revolutionary trends across industries in the past few decades is the move toward "green" products. As concerns grow over the risk posed to humans and ecosystems by synthetic materials, more natural alternatives are being explored. This effort was spearheaded in the 1990s by the EPA's Green Chemistry program, with principles such as increasing energy efficiency and preventing waste, and global attitudes have overall shifted favorably toward greener production processes.

A paper published in the *Journal of Surfactants and Detergents* by Vivek Rangarajan, a chemical engineer at Birla Institute of Technology and Science, in Pilani, India, explores the intersection between the trend toward greener goals and another increasingly popular domain: nanoemulsions (https://doi.org/10.1002/jsde.12571). Nanoemulsions, otherwise known as ultrafine emulsions, are particulate systems with oil and water phases dispersed into one another via amphiphilic molecules called surfactants. They have been used across a wide variety of fields, such as drug delivery, agriculture, and cosmetics, because of their unique properties.

In the past few years, the features offered by nanoemulsions have been of great interest to the cosmeceuticals industry. Their long-term stability, higher drug solubilization, and bioavailability are particularly enticing, and their small particle size allows for use in health care products as they can easily penetrate through bodily membranes and transport active substances.

Rangarajan's paper examines the various benefits and downsides of green nanoemulsions—specifically in the growing cosmeceuticals industry. While there seem to be many opportunities for growth in this area, some challenges must be addressed.

One such difficulty is selecting an emulsifier for the system. With the use of nanoemulsions for targeted drug delivery systems, it is crucial that emulsifiers have very low toxicity,



GRAPH 1. A comparison of two biosurfactants, surfactin and di-rhamnolipid, for use in nanoemulsions. Source: Rangarajan, V., *et al.*, *J Surfact Deterg.*, 2022

because they come into direct contact with human cells. This is particularly relevant with nanoemulsion use in cosmetics and food products.

When selecting a biosurfactant (a compound which lowers surface tension between the oil and water phases) to use as an emulsifier, it is crucial to examine its efficacy compared to the synthetic surfactants it will replace. Two different biosurfactants were highlighted in Rangarajan's paper: microbial-derived rhamnolipids (RLs) and surfactin (a cyclic lipopeptide). Their properties were found to be comparable to synthetic surfactants, and they could produce fairly stable systems that show promise for future research.

One recent study involving the use of surfactin as an emulsifying agent, shows its potential for use in the cosmetics industry. The study aimed to formulate a self-emulsifying drug delivery system using surfactin as the emulsifier; a system of active compounds (vitamin C and E), cosolvents, surfactant, cosurfactant, oils, and water phases was used. The bioactive components reduced vascular lesions, discoloration, and intensity of wrinkles on tested skin, and the shelf life of the final system was nearly 200 days. While this study was performed on a small scale, the efficacy of the tested nanoemulsion shows huge potential for further use of surfactin as an emulsifying agent (https://doi.org/10.3390/pharmaceutics12100953).

While RLs and surfactin are promising, there are some difficulties related to compound formation that may prove a challenge for industrial use. Microbial fermentation, the primary method for obtaining RLs, has given rise to RLs with variations in the number of rhamnose molecules, yielding both mono and di-RLs. Because of this, it is inevitable that both variants will be present in the final fermentation broth. Although both mono and di-RLs are useful in nanoemulsions (mono RLs are less hydrophilic and have better emulsifying activity, whereas di-RLs are better at surface reduction), the ratio between the two needs to be tightly controlled so that the final system is sufficiently stable.

In addition to such technical challenges, the cost of manufacturing and purification steps for producing RLs are high, making mass production difficult. While RLs are biocompatible, biodegradable, and less toxic than their synthetic predecessors, they can cost up to 20 times more to produce, mainly due to the difficulty of finding appropriate carbon and nitrogen sources to feed microbes. Because hydrophobic substrates are used instead of sugar-based substrates to increase product yield, the cost of raw materials can account for as much as 50% of total RL production costs. Surfactin is no cheaper; their production costs are higher than any chemical surfactant. As a result, their usage has been limited.

While both RLs and surfactin have proven useful in the lab, the challenge of their high cost is one that must be addressed for their industrial applications. Even so, their potential for premium skincare products is substantial.

Besides the emulsifying agent, an oil must be chosen in the creation of a nanoemulsion. There is a wide variety of natural oils that can be used in a green nanoemulsion, and the specific type has great influence on the effect and potential use of the overall system. Typically, a nanoemulsion contains more than one type of oil; for example, a base oil can serve as a moisturizing and stabilizing agent, while an essential oil may be used for its antioxidant or antimicrobial properties.

The range of useful essential oils is vast, and they can be used for various specific applications in cosmetics. For example, carrot seed oil has been shown to possess antiaging, antibacterial, and antioxidant properties in skincare; it is usually paired with coconut oil, which functions as a carrier oil and additionally possesses antifungal and anti-inflammatory properties (https://doi.org/10.4236/FNS.2014.522227). Other frequently used essential oils include raspberry seed oil, peach kernel oil, sunflower oil, and eucalyptus oil. As Rangarajan outlined in his paper, the differing features of essential oils make them promising candidates for natural nanoemulsions.

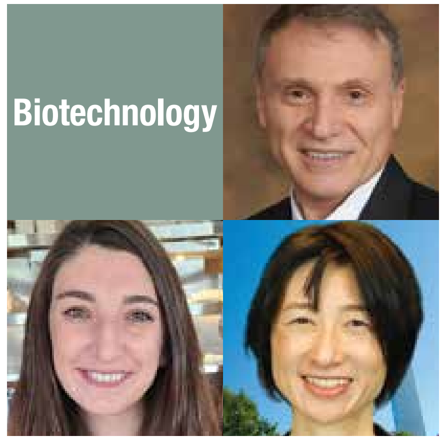
The type and concentration of oil must be carefully controlled for the nanoemulsion to be stable; otherwise, the system may fall victim to a process called Ostwald ripening. This destabilization phenomenon causes solubilized oil molecules to go from small to large droplets and can be due to temperature as well as the components of the emulsion. To combat this, it is crucial to select a carrier oil that contributes positively to the stability of the nanoemulsion.

Although there are various significant challenges surrounding green nanoemulsions, their chemical properties and eco-friendly qualities are enticing across industries. As consumers grow more environmentally conscious, it is vital to pay attention to factors such as biodegradability and sustainability; similarly, the lower toxicity of biosurfactants compared to synthetic emulsifiers is vastly beneficial to human health.

While it is wrong to presume that natural alternatives are totally safe and always more sustainable, the intersection between the green trend and growing science around nanoemulsions is not one to be ignored. Extensive studies are needed to address problems such as scaling up from the lab, and cost-effective methods must be addressed in order to produce green nanoemulsion components at an industrial level. However, even with these difficulties, the future of green nanoemulsions is bright.

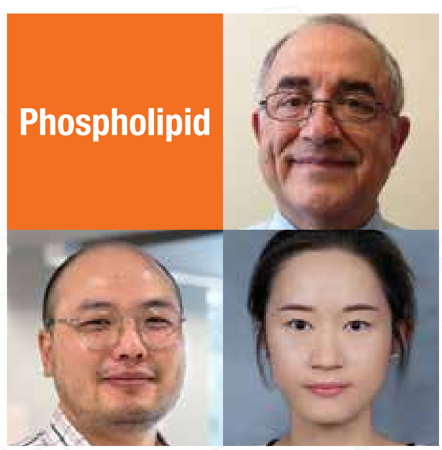
Introducing the 2022–2023 AO

Chair: Lisa Clement, *Cargill Inc., USA*
Vice Chair: Giorgia Purcaro, *University of Liege, Belgium*
Secretary-Treasurer: Francesca Giuffrida, *Nestle Research, Switzerland*

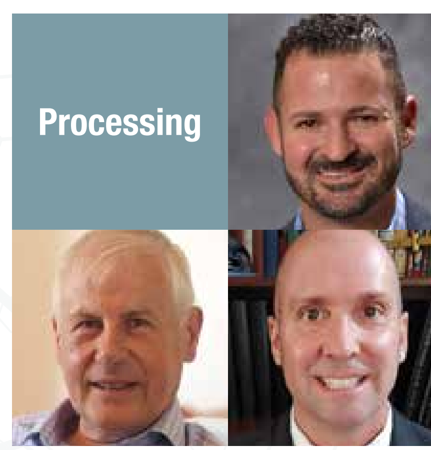


Chair: Tim Ulmasov, *CoverCress, Inc., USA* ◈
Vice Chair: Sarah Willett, *Kerry, Inc., USA* ◈
Secretary-Treasurer: Yomi Watanabe, *Osaka Res Inst of Industrial Science & Technology, Japan*

Chair: Kaustuv Bhattacharya, *IFF, Denmark* ◈
Vice Chair: Filip Van Bockstaele, *Ghent University, Belgium*
Secretary-Treasurer: Andrew Gravelle, *University of California-Davis, USA* ◈



Chair: Ernesto Hernandez, *Advanced Lipid Consultants, USA*
Vice Chair: Tao Fei, *Huzhou Agricultural Bureau, China*
Secretary-Treasurer: Zifan Wan, *University of Wisconsin-Platteville, USA* ◈

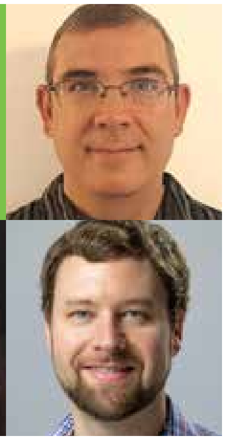


Chair: Michael (Mike) Martinez, *Natural Plant Products, Inc., USA*
Vice Chair: Alan Paine, *Consultant, United Kingdom*
Secretary-Treasurer: Darren Litle, *Arisdyne, USA*

AOCS
Your Global Fats and Oils Connection

CS Division leadership teams!

Health and Nutrition



Chair: Ignacio Vieitez, *PEDECIBA Quimica-UdelaR, Uruguay* ◈
Vice Chair: Rinat Ran-Ressler, *Nestle, USA* ◈
Secretary-Treasurer: Jake Olson, *TerViva, USA*

Industrial Oil Products

Chair: Eric Cochran, *Iowa State University, USA*
Vice Chair: Brajendra (BK) Sharma, *USDA ARS ERRC, USA*
Secretary-Treasurer: Mahjer Sarker, *USDA, USA* ◈

Lipid Oxidation Quality

Chair: J. David Pinkston, *ADM, USA*
Vice Chair: David Johnson, *Kalsec, USA*
Secretary-Treasurer: Marc Pignitter, *University of Vienna, Austria*

Protein and Co-Products

Chair: Lamia L'Hocine, *Agriculture & Agri-Food Canada (AAFC), Canada*
Vice Chair: Lingyun Chen, *University of Alberta, Canada*
Secretary-Treasurer: Kaustav Majumder, *University of Nebraska, USA*

Surfactants and Detergents

Chair: Keith Genco, *Arkema, Inc., USA*
Vice Chair: Sanja Natali, *ExxonMobil, USA*
Secretary-Treasurer: Hongwei Shen, *Colgate-Palmolive Company, USA*

For more information or to join a Division
aocs.org/divisions

◈ New 2022–2023

Division Name	Chair
Vice Chair	Sec-Treas

An argument against excessive safety assessments for newly expressed proteins

Regulatory Review is a regular column featuring updates on regulatory matters concerning oils- and fats-related industries.

Phil Brunea, Suma Chakravarthyb, Gerson Grasera, et al.

Since the commercial introduction of genetically modified(GM) plants in 1994, regulatory decisions have been made internationally to authorize their use for food and feed and for cultivation. In 2003, the Codex Alimentarius Commission (Codex) published guidelines for conducting safety assessments of GM plants that have constituted the basis for developers and global regulatory authorities to evaluate their safety.

To date, regulatory agencies have issued over 3,500 approvals for the use of GM plants for food and feed (https://tinyurl.com/ybwh3zbc). Although experience and scientific knowledge about GM plants has expanded, regulatory requirements for scientific data have been increasing disproportionately with the observed potential for risk.

Even with the continued relevance of the Codex guidelines, there is an opportunity to leverage both the familiarity and established history of safety of GM plants to revise the safety assessment approach, given the expanded experience of product developers, regulatory authorities, and researchers. As further discussed in Waters *et al.*, current scientific understanding and experience warrants redefining the studies that are sufficient to evaluate whether a GM plant is as safe as its conventional counterpart (https://doi.org/10.21423/jrs-v09i1waters).

As outlined in Waters *et al.*, when the weight-of-evidence from core studies is not sufficient to determine the absence of hazard, supplementary studies may provide additional hazard characterization and/or exposure characterization to better understand the hazard presented by the newly expressed protein (NEP). As an example, one of the studies proposed to be supplementary is dietary exposure assessment, which is unnecessary if the weight-of-evidence supports a conclusion of low or negligible hazard associated with consumption of a GM plant (https://doi.org/10.2903/j.efsa.2017.4971). However, if the weight-of-evidence failed to provide support for a low or negligible hazard conclusion, a supplemental dietary exposure assessment and other supplemental data may be necessary to conclude on risk (https://doi.org/10.21423/jrs-v08mathesius).

As previously discussed, thousands of safety assessments conducted globally have been consistent in their outcomes. Consequently, some jurisdictions have chosen to implement a streamlined and pragmatic approach to regulate GM plants for food or feed use by empowering the appropriate governmental body to authorize products based on the safety determinations of authorities in one or more other countries. This allows for efficient use of regulatory resources while maintaining a high level of safety for human/animal health and the environment. This approach to regulation is also embedded in the Codex guidelines which clearly state that "where appropriate, the results of a risk assessment undertaken by other regulatory authorities may be used to assist in the risk analysis and avoid duplication of work."

We recommend a core set of studies that focus on characterization and safety assessment of the introduced trait. These recommendations are modified from earlier guidelines and recommendations for the safety assessment of GM plants. Using the data resulting from the recommended core studies, and employing a "problem formulation" approach, the need for supplementary hypothesis-driven or case-by-case studies can be determined.

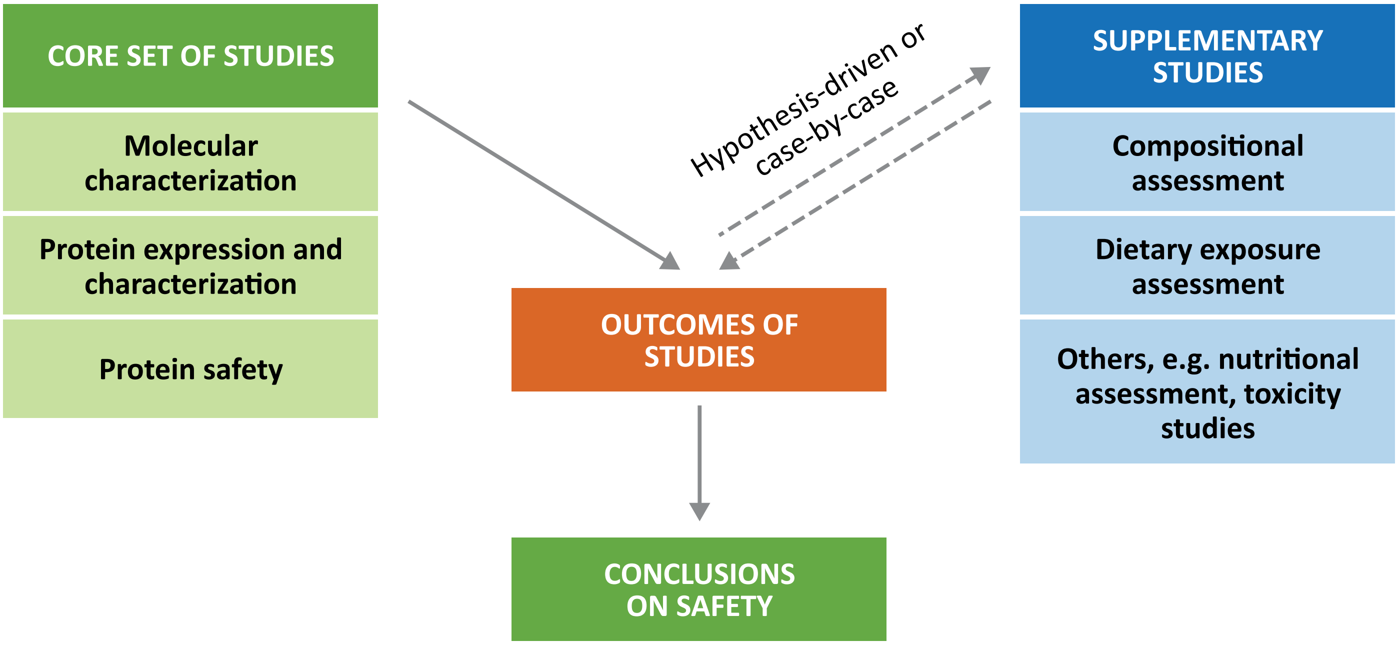


FIG. 1. Schematic representation of core and supplementary studies for typical GM plants. Core studies are a set of studies necessary for a science-based risk assessment of a GM plant. Supplementary studies depend on the nature of the introduced trait, intended use and data obtained from core studies. Source: Schnell, *et al.*, *Transgenic Research, 24*(1), 1-17, 2015.

CORE STUDIES: CHARACTERIZATION AND SAFETY ASSESSMENT

It is noted that there may be alternative newly expressed substances that are not addressed in this manuscript; however, the principles presented could also apply to other expression products that do not result in a NEP. The suggested core studies for typical (i.e., sexually propagated) GM plants producing a NEP are shown in figure 1.

The integrity and genetic stability of the introduced DNA and expression of the trait should be evaluated for all GM plants. Molecular and protein characterization are core characterization studies. Some data obtained from these studies also inform certain aspects of the protein safety assessment.

Further studies, routinely required to complete the molecular characterization requirements established by certain regulatory authorities, should not be considered core or supplementary studies, because they do not inform the safety assessment. These studies are discussed in Box 1.

SUPPLEMENTARY STUDIES: TOXICITY

The toxicological evaluation of all NEPs as a default assessment is not hypothesis-driven, nor supported by the current weight-of-evidence. As discussed in Roper *et al.*, "defaulting to in vivo toxicology studies, as is often required for regulatory approvals, does not reflect ethical use of animals in scientific research and testing as outlined by the 3R's of responsible animal use (Replacement, Reduction and Refinement) that have been increasingly incorporated into regulatory in vivo studies" (https://doi.org/10.21423/jrs-v09i1roper).

Acute oral toxicology studies with proteins should only be conducted if deemed necessary to address specific hazard hypotheses arrived at through problem formulation. When toxicity studies are deemed necessary, acute toxicity studies are generally sufficient given the observation that, while most proteins do not present a hazard, most protein toxins elicit their toxicity through acute mechanisms of action. Evidence to date for NEPs in GM crops indicates that when no hazard is identified, no evidence of adverse effects is observed in acute oral toxicology studies. Nevertheless, acute toxicology studies are still required by many regulatory authorities regardless of the nature of the protein.

The routine requirement for repeated dose toxicity studies with proteins in the safety assessment of GM plants is also not scientifically justified, as discussed in Box 2. No evidence exists to suggest that protein digestion is altered as a result of repeated exposure or consumption of proteins. Furthermore, most protein toxins act acutely, and therefore, do not have repeated dose or cumulative toxicity.

Based on the compelling body of evidence collected since Codex guidelines were developed, it is recommended that a compositional assessment of a new GM plant should follow a stepwise approach to determine if further data generation is necessary, and if so, what data should be collected. The goal of this approach is to focus the compositional assessment on the key components that are critical to the nutritional and/or safety considerations for the crop and also have potential to be altered by the introduced trait(s) (Figure 2), since not all compositional changes are an indicator of a hazard.

Our proposal is to first formulate sound hypotheses, based on the trait mode of action, to further refine the list of components to be targeted for analyses, and then use a stepwise approach to evaluate known information and decide what additional information is necessary to inform the safety assessment as detailed in Box 3.

BOX 1 Bioinformatic assessments enabled by molecular characterization that do not provide additional value to the safety assessment

The assessments below are typically performed to meet current registration requirements in specific jurisdictions, but are not universally required and do not inform the safety assessment for GM plants.

Open Reading Frames (ORF) bioinformatic analysis: The bioinformatic assessment of ORF in the insert and adjacent flanking genomic sequence is performed to determine if non-canonical transcription and/or translation can yield a novel protein sequence that is allergenic, toxic, or displays some other undesirable characteristic such as inhibition of proteases or nucleases found in animal digestive systems. Unlike the bioinformatic evaluation of the actual transgene-encoded protein itself (which is confirmed through protein characterization studies), the analysis of potential ORF created due to transgenic insertion is theoretical and disregards basic biological processes.

Theoretical ORF analysis provides no additional value to a safety assessment, unless the ORF contains contextually correct initiation codon and is appropriately located relative to promoter and terminator (or gene expression) elements. Such detail would be uncovered through inspection of the organization of genetic elements in the transgenic insert sequence, which is included within the core molecular characterization studies. Furthermore, the potential for an unintended ORF generated through transgenic insertion is no greater than that for conventional breeding, and a safety issue arising from such random events is statistically negligible, consistent with the history of safety for new crop varieties (both conventional and GM).

Repeated bioinformatic analyses for endogenous genes: Although obtaining genomic flanking sequences for determining whether an endogenous gene was disrupted is required by some regulatory authorities, this analysis is not necessary to support the safety assessment of GM crops, as the risks associated with disrupting gene by insertion of transgenic DNA is the same or less than that for conventional breeding. When bioinformatic analysis are performed with well-annotated genome assemblies, definitive conclusions on the interruption or deletion of endogenous genes can be drawn. The database update of genomic assemblies including new information on gene annotation, function, etc., should not alter the conclusions made initially if the region of the recipient genome is not changed in the updates. Since gene disruption is not a unique risk of transgenesis, repeated bioinformatic analyses do not add value to safety assessments.

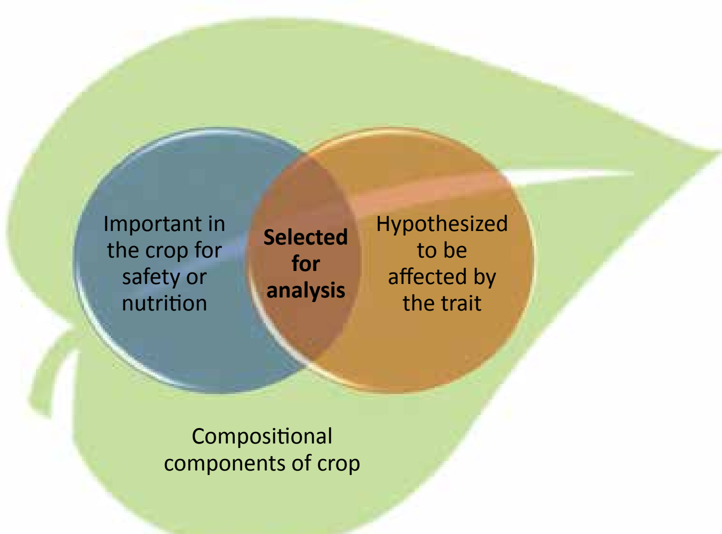


FIG. 2. Component selection for genetically modified (GM) plant composition analyses in support of food and feed safety assessment. Source: Brune, *et al.,J Reg Sci 9*(1), 45–60, 2021.

As an example of implementation of the proposed approach, consider the tyrosine catabolic pathway and a trait that affects levels of hydroxyphenylpyruvate (HPP). HPP is dehydrogenated into homogentisate, which is upstream from the tocochromanols (tocopherols and tocotrienols). (α-Tocopherol is the most biologically active form of vitamin E in the diet). All tocopherols and tocotrienols act as antioxidants when present in vegetable oils, preventing development of rancidity. The null hypothesis to test is that there are no differences in levels of tocopherols and tocotrienols between the GM crop and its non-GM comparator. There is no reasonable expectation, and thus no sound hypothesis, that the trait, based on its mode of action, would affect other crop components outside of this pathway (e.g., levels of minerals, crude protein, dietary fibers) anymore than is possible with conventional breeding. Therefore, the components to be measured and compared should only be those hypothesized to be impacted as a result of the trait mode of action and impacting health or safety. Generation of other data for unrelated components is superfluous and would be detracting from the safety assessment of the novel GM crop.

BOX 2 Routine 28-day and 90-day repeated dose toxicity studies are scientifically unjustified.

If the NEP is related to a family of proteins that has a history of safe use based on bioinformatics and literature review, and is not homologous to known protein toxins, then any supplementary toxicology study is not necessary. Furthermore, if an acute oral toxicology study has been performed with no observed adverse effects, then a 28-day repeated-dose toxicity study with the protein is unlikely to contribute any additional valuable information to the protein safety assessment.

The routine requirement for a 90-day toxicity study with whole food (e.g., grains) in the safety assessment of GM plants is also not scientifically justified. However, these studies are required in some countries to supplement the molecular and compositional data included in the risk assessment, even in the absence of a plausible risk hypothesis. Studies to date have shown that unintended effects on the composition of GM plants occur less frequently and are of a lower magnitude as a result of the process of genetic modification or transformation compared with their occurrence in traditionally-bred crop varieties.

When a 90-day study is performed to meet individual country requirements, it is performed by feeding whole food/feed material, ostensibly to identify potential adverse effects of consumption of edible fractions from GM plants. The methods are principally based on existing guidance for the identification and characterization of potential hazards of chemicals from repeated oral administration during a critical period of animal growth and development, with necessary adaptations for evaluation of whole food and feed. Although the study design provides satisfactory estimates of no-effect and no-adverse-effect levels, the incorporation of whole food or feed fractions into these studies has inherent limitations for exposure due to nutritional and satiety concerns that impact animal performance irrespective of the GM crop fraction included in the diet. Additionally, feeding studies conducted in the absence of a risk hypothesis are generally considered to lack sufficient sensitivity to yield meaningful results relevant to the safety assessment of GM plants, create challenges for study design due to difficulties in determination of adequate sample size for appropriate statistical power, place undue emphasis on feeding study results in comparison with other components of the safety assessment, and are inconsistent with the principles of reduction, refinement, and replacement of animals in research. These conclusions have been reinforced by the recent completion of two European Commission work programs, GMO Risk Assessment and Communication of Evidence and GM Plants Two Year Safety Test (https://cordis.europa.eu/project/id/632165/reporting). The findings of these European projects are consistent with those presented above that 90-day feeding studies with GM food/feed materials are scientifically superfluous to the overall risk assessment.

This hypothesis-driven approach is also in line with the problem formulation approach described by Raybould and MacDonald for environmental risk assessment of GM crops, who emphasized that there should be movement, "toward hypotheses that help decision-making and realization of policy objectives" (https://doi.org/10.3389/fbioe.2018.00043).

The automatic requirement of in-depth, multi-component compositional studies within the set of safety evaluations of a new GM crop has been called into question by the increasing body of knowledge regarding the extent of natural variation in crop composition, the innate variability and plasticity in plant genomes, and the empirical evidence supporting a negligible impact of the transgenesis on composition. The hypothesis-driven approach to compositional studies described here serves to characterize the impact of the trait(s) on the levels of the targeted components. This focused approach is consistent with the established practices of conventional variety registration and meets food and feed product standards.

SUMMARY AND CONCLUSION

Earlier guidelines and recommendations for the safety assessment of GM plants containing NEPs still provide a valid resource for the risk assessment of GM plants. However, given the history of safety and familiarity after many years of experience with these products, it is time to reconsider the approach to safety assessments for GM plants.

Despite the accumulated knowledge and familiarity of developers, academic scientists, and regulators with GM plants, regulatory reviews of their safety for food and feed use continue to be inconsistent internationally. In some cases, the safety assessment data required has continued to increase without adding value to the risk assessment.

Here we presented, a systematic approach for the safety review of GM plants used as food or feed. A set of core studies is recommended, including characterization and protein safety assessment. It is important to perform hazard identification in core studies, and if hazard is determined to be negligible, then

BOX 3 Recommended stepwise approach for compositional assessment

At each step, a decision is made whether the available information is sufficient to assess possible risk or whether additional information may be needed (e.g., further information concerning mode of action, generation of appropriate data to address the hypothesized risk).

STEP 1: Based on knowledge of the mode of action or function of the introduced GM trait, determine whether a supplementary compositional study will be useful for informing the overall risk assessment.
GM plants possess specific phenotypic traits determined by the mode of action of the introduce genetic material. The expected functional or biological activity of the intended genetic modification is studied prior to commercialization of the new GM plant (information gained from core studies). A compositional study is not necessary if there is no scientifically reasonable hypothesis that the GM trait introduction will compromise crop composition in a manner that could lead to a safety or nutritional concern. For some GM traits, there is a reasonable hypothesis, based on the mode of action or function of the introduced trait, to justify a compositional assessment. If the outcome of Step 1 concludes that a targeted compositional assessment is necessary to address hypothesized changes in composition, then the assessment proceeds to Step 2.

STEP 2: Determine which components are relevant to include in a composition study.
In cases where a composition study will provide informative data that are meaningful to the safety assessment, the decision on which components to include are limited to those components that are predicted to be both affected by the introduction of the trait and relevant to the safety or nutritional properties of the crop. If levels of the selected components are within what is considered typical for the crop, no further assessment is necessary. If the introduction trait is predicted to potentially result in the production of a metabolite novel to the crop, then levels of this metabolite are to be evaluated as well. If the assessed components are present at levels outside the natural range for the crop commodity, or if further evaluation of a novel metabolite is deemed necessary, then Step 3 is performed.

STEP 3: Evaluate the safety and nutritional relevance of altered component levels
The focused compositional analysis may indicate that the level of one or more components falls outside the range of values previously observed for the crop commodity. However, such a result does not necessarily signify that the new GM plant is less safe, but that further assessment of the implications of the change may be necessary. The scope of the additional assessment would depend on the nature of the change and on the intended use(s) of the crop. Particular component changes could mandate a change in the use of, or the level of inclusion in, downstream products (e.g., processed food/feed). For example, the level of inclusion of cottonseed meal in livestock diets can be influenced by the level of anti-nutrient gossypol, and the functionality of soybean oil used in food service or processed food could be impacted by intentional alterations in its fatty acid profile. Novel metabolites would be similarly assessed for possible impacts to safety and nutrition: history of safe use of the metabolite, levels of exposure from other food sources, etc.

core studies should be sufficient to conclude that the GM plant is as safe as its conventional comparator.

Rather than making additional assessments a routine requirement, these additional assessments would only be needed if, given the trait mode of action, the hazard and exposure assessments from the core studies were not conclusive. Only when the information from the core studies is clearly not adequate to conclude on risk, may supplementary studies be necessary.

Waters *et al.* present a compelling rationale and concepts for the adoption of science-based approaches to GM plant safety assessment, and the present article details a systematic approach to evaluate the safety of GM plants. This approach to safety assessment could provide a first step towards standardizing requirements across regulatory systems based on current scientific knowledge and over 25 years of experience in the development and food/feed safety assessment of GM plants.

Meet Ece Gulkirpik

Member Spotlight is a slice of life that helps AOCS members get to know each other on a more personal level.

Ece Gulkirpik on the colorful grounds of the University of Illinois at Urbana–Champaign, where she is a PhD candidate.

Fast facts

Name	Ece Gulkirpik
Joined AOCS	2019
Education	BSc in food engineering from the Istanbul Technical University (Istanbul, Turkey)
Job title	PhD candidate (expected to graduate in May 2022); graduate research and teaching assistant
Employer	University of Illinois at Urbana–Champaign (UIUC)
Current AOCS role	Chair, AOCS Student Common Interest Group

PROFESSIONAL

What's a typical day like for you?
A typical day starts early for me at around 6 am. I've been working with scientists in the Sub-Saharan Africa region for my dissertation study through the Soybean Innovation Lab at UIUC. Because of the time difference, we usually have team meetings early in the morning. After these meetings, I spend most of my time working at the lab.

My favorite part of my job is…
Contributing to finding a solution for one of the world's most important problems: global food insecurity.

Flash back to when you were 10 years old. What did you want to be when you grew up?
I wanted to be many things, to be honest: a doctor, an architect, an artist, a chef, etc. But I remember that I was always passionate about food.

Why did you decide to do the work you are doing now?
My passion for food science stems in part from being raised by a family who let me live the joy of sharing food and honoring the long culinary tradition of our Turkish culture. As an international student from a developing country, I'm also aware of the need for change in the current food system. I aim to combine my engineering background and interest in nutrition to create sustainable food systems to enable everyone to access safe and sufficient food. My doctoral research is, therefore, focused on developing and evaluating processing technologies to improve the utilization of soybean products and to promote the health and nutrition of vulnerable populations in low-resource settings.

PERSONAL

How do you relax after a hard day of work?
It depends how tired I feel. If it is a day filled with lab work, I prefer to stay at home, watch my favorite shows on Netflix such as *Squid Game* and *La Casa de Papel*, maybe listen to some music, and rest. However, if I still have some energy, I go out to play tennis or hang out with my friends.

What skill would you like to master?
I would like to improve my data visualization and presentation skills. Grad school taught me that performing science in the lab is very important, but communicating the results of that work—in other words, delivering the story behind one's research and answering the "why" questions—are as important as your scientific skills. And one of the ways to explain your work efficiently is to be able to use data visualization and presentation tools effectively.

What are some small things that make your day better?
Video calls with my family in Turkey always brighten my day. Their endless love and support are my biggest motivation.

PATENTS

Method for the simultaneous production of ethanol and a fermented, solid product

Hansen, O.K., *et al.*, Hamilton Protein, US11078500, August 3, 2021

The invention relates to a method for the simultaneous production of a fermented, solid product and ethanol comprising the following steps: 1) providing a mixture of milled or flaked or otherwise disintegrated biomass, comprising oligosaccharides and/or polysaccharides and live yeast in a dry matter ratio of from 2:1 to 100:1, and water; 2) fermenting the mixture resulting from step (1) under conditions where the water content in the initial mixture does not exceed 65 percent by weight, for 1-36 hours at a temperature of about 25-60 degrees centigrade under anaerobic conditions; 3) incubating the fermented mixture resulting from step (2) for 0.5-240 minutes at a temperature of about 70-150 degrees centigrade; and 4) separating wet fermented, solid product from the fermented mixture resulting from step (3); further comprising either a) that the fermentation in step (2) is performed in one or more interconnected paddle worm or continuous worm conveyers with inlet means for the fermentation mixture and additives and outlet means for the ferment as well as control means for rotation speed, temperature and pH, or b) that one or more processing aids are added in any of steps (1), (2) and (3) and further comprising a step of 5) separating crude ethanol from the fermented mixture in step (2) by vacuum and/or in step (3) by vacuum or by injection of steam and condensing the surplus stripping steam. The invention further relates to the products of this method as well as uses thereof.

Silica adsorbent treatment for removal of chlorophyll derivatives from triacylglycerol-based oils

Dayton, C., *et al.*, Bunge Global Innovation LLC, US11098265, August 24, 2021

The present invention relates to a process for treating an oil comprising a chlorophyll derivative. In particular, the present disclosure relates to an improved process for removing impurities, including chlorophyll derivatives and/or trace metals, from an oil using an adsorbent comprising a silica treated with an alkali earth metal oxide, such as magnesium oxide. The process comprises contacting the oil with the adsorbent, wherein the pH of the silica is about 7 or greater, including from about 7 to about 10. The process may further comprise contacting the oil with a polypeptide having decolorase activity or a composition comprising the polypeptide, prior to contact with the adsorbent.

Method for producing phospholipid concentrate

Yuasa, K., *et al.*, Marudai Food CoLTD, US11091720, August 17, 2021

This invention provides a technique that is capable of efficiently producing a phospholipid concentrate without using centrifugation and that is suitable for scaling up, the technique being for use in obtaining a phospholipid concentrate by subjecting an ethanol extract concentrate of bird breast meat to a degumming step and collecting gum. More specifically, the invention provides a method for producing a phospholipid concentrate, comprising a step of allowing a liquid mixture comprising an ethanol extract concentrate of bird breast meat and a 40 to 60 mass percent aqueous ethanol solution in a mass ratio of 1:0.8 to 1.2 to stand at 40 to 60 degrees centigrade

Enzymatic degumming of unrefined triglyceride oil

Marques de Lima, D., Purac Biochem, US11091721, August 17, 2021

The present invention provides a process for the enzymatic degumming of unrefined triglyceride oils, said process comprising: a) providing an unrefined triglyceride oil having a phosphorus content of at least 100 mg per kg of unrefined triglyceride oil;b) combining the unrefined triglyceride oil with water, lactic acid and enzyme to produce an oil-and-water emulsion, said enzyme being selected from phospholipase, lipid acyltransferase and combinations thereof;c) keeping the emulsion at a temperature of 20-90 degrees centigrade for at least 10 minutes; andd) separating degummed triglyceride oil from the emulsion.

This enzymatic degumming process is extremely effective in removing phospholipids, including non-hydratable phospholipids (NHP), from crude and other unrefined vegetable oils."

Biological oils and production and uses thereof

Lippmeier, J.C., *et al.*, DSM IP Assests BV, US11104923, August 31, 2021

The present invention provides biological oils and methods and uses thereof. The biological oils are preferably produced by heterotrophic fermentation of one or more microorganisms using cellulose-containing feedstock as a main source of carbon. The present invention also provides methods of producing lipid-based biofuels and food, nutritional, and pharmaceutical products using the biological oils.

Patent information was compiled by Scott Bloomer, a registered US patent agent and Director, Technical Services at AOCS. Contact him at scott.bloomer@aocs.org.

Special collection on the HLD model

The May issue of the *Journal of Surfactants and Detergents (JSD)* will be supplemented online by a special collection of recent publications on the hydrophilic-lipophilic deviation method. The virtual issue, available on the journal's website, was compiled by George A. Smith, research associate at Sasol in Westlake, Louisiana, USA. Smith is currently one the journal's associate editors and previously served as its editor-in-chief. The special collection includes articles that cover the history of the theory's development, as well as its application in washing agents and oil recovery (https://aocs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1558-9293.HLD).

Smith opens the collection with an editorial describing how the theory originated in the cosmetic industry. In the early 1950s, William C. Griffin developed the hydrophilic-lipophilic balance (HLB) as a way to predict the surfactant properties of a molecule (Fig. 1). Although providing a good first approximation, the HLB fails to account for a solution's temperature, solvent, salinity, or cosurfactants, among other properties.

"One of the main problems with the HLB concept is that it assumes the balance between hydrophilic and lipophilic forces is based solely on the structure of the surfactant," writes Smith. "Anyone who has worked with surfactants soon realizes that the balance depends on the system in which the surfactant is present."

By contrast, the hydrophilic-lipophilic deviation (HLD) equation (sometimes called the hydrophilic-lipophilic difference) predicts the behavior of surfactants as part of a multicomponent system under a variety of experimental conditions. The more inclusive theory is now used in a variety of applications, like oil recovery, consumer products, and surfactant manufacturing.

The virtual issue contains two papers from a four part series on enhanced oil recovery (EOR) written by Professor Jean-Louis Salager of the University of the Andes in Mérida, Venezuela and *JSD* editor-in-chief emeritus. For over 40 years, Salager and his students have been publishing research on HLD. Along with an overview of the HLD concept, the selected papers cover practical matters associated with three surfactant mixtures and microemulsion systems.

Two papers by Edgar Acosta and co-workers at the University of Toronto, Canada explain the surface characteristic parameter of surfactants which they calculated using reference water-oil-surfactant mixtures. The characteristic sur-

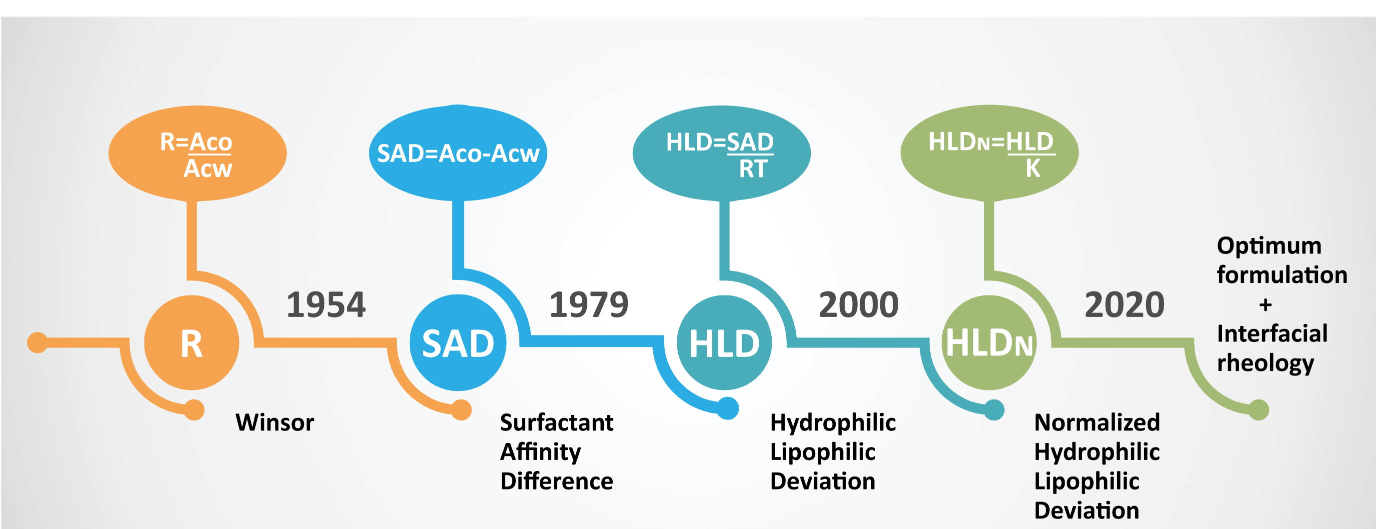


FIG.1. The evolution of mathematical theories used to calculate the balance between hydrophilic and lipophilic interfacial interactions for a surfactant molecule in a multicomponent system. Source: Marquez, *et al.*, *JSD*, *24*, 587-601, 2021.

factant parameter was calculated by applying the HLD model using optimal salinity, interfacial tension, and emulsion stability test results as inputs. In Acosta's second paper in the collection, he and co-authors use this approach to predict phase behavior of alcohol ethoxylate surfactants.

According to Smith: "Since its inception in the 1970s, the HLD concept has been used to help formulate surfactant systems for EOR. Some confusion concerning the characteristic surfactant parameters determined using different scales has occurred over the years." To address this, the HLD model has been fine-tuned with several addenda.

The special collection includes recent publications that address these optimizations, including:

- a normalized HLD_N expression using the alkane carbon number (ACN) scale of an oil to predict microemulsion phase behavior
- a free-energy model to explore optimal conditions for nonionic surfactants in detergents
- using phase inversion temperature (PIT) and interfacial tension (IFT) measurements to derive the characteristic surfactant parameter

The remaining papers in the collection pertain mostly to applications of the model in recent years. They include using the method to predict cloud point formation or a microemulsion system to remove crude rice bran oil from spent bleaching earth.

In addition, extended chain surfactants have potential in industries such as EOR, emulsion breaking, detergent formulation, and as drug delivery vehicles in cosmetic formulations. Multiple papers focus on using the model to study extended chain surfactants, including:

- using a mixture of extended chain ether sulfates and dioctyl sulfosuccinate to examine hydrocarbon soil removal from polyester/cotton blends
- extended chain surfactants for EOR applications
- extended chain surfactants for solubilizing polar oils
- extended chain surfactants in cold water detergents

"Great progress has been made over the last few years to further develop the applicability of the HLD equation and extend it to more complex formulations and to additional applications," writes Smith. The HLD model simplifies the process of identifying the ideal structure of the surfactant, including the alkyl chain length to formulate surfactant systems that can dissolve a complex mixture of hydrocarbon and triglyceride soils. According to Smith, future research will concentrate on the effect of surfactant partitioning and liquid crystal formation.

We hope you enjoy the virtual issue. And stay tuned for highlights from a special session celebrating the *Journal of Surfactants and Detergent's* 25th Anniversary at the AOCS 2022 Annual Meeting and Expo coming up in the July/August issue of INFORM.

EXTRACTS & DISTILLATES

The full version of all AOCS journal articles are available online to members at www.aocs.org/journal. This column builds on that member benefit by primarily highlighting articles from other journals.

ANA Analytical
BIO Biotechnology
EAT Edible Applications
LOQ Lipid Oxidation and Quality
H&N Health and Nutrition
IOP Industrial Oil Products
PRO Processing
PCP Protein and Co-Products
S&D Surfactants and Detergents

Review Articles

EAT An insight into the physicochemical characterization of starch-lipid complex and its importance in food industry

Sengupta, A., *et al.*, *Food Reviews International*, In press, 2022, https://doi.org/10.1080/87559129.2021.2021936

The interaction between starch and lipid gives rise to complexes that have various applications in the food industry. These complexes are known to be useful in food technology, where they influence the texture and quality of the food product, along with various other characteristics. For example, they can be used as fat replacements in different food products, delay the staling of food, improve the freeze thaw stability of products, also can be used to control the glucose levels in patients with diabetes, etc. Various techniques are used to study the structural, thermal, and chemical characteristics of these starch-lipid complexes including X-ray diffraction (XRD), scanning electron microscope (SEM), differential scanning calorimetry (DSC), and Fourier transform infrared (FTIR) spectroscopy. This review outlines the formation of the starch-lipid complexes, their value in the food industry, the varying effects on different types of starch and lipids in food products, and characterization of these complexes .

BIO Advances in production of high-value lipids by oleaginous yeasts

Szczepańska, P., *et al.*, *Critical Reviews in Biotechnology*, 42, 1-22, 2022, https://doi.org/10.1080/07388551.2021.1922353

The global market for high-value fatty acids production, mainly omega-3/6, hydroxy fatty-acids, waxes and their derivatives, has seen strong development in the last decade. The reason for this growth was the increasing utilization of these lipids as significant ingredients for cosmetics, food and the oleochemical industries. The large demand for these compounds resulted in a greater scientific interest in research focused on alternative sources of oil production - among which microorganisms attracted the most attention. Microbial oil production offers the possibility to engineer the pathways and store lipids enriched with the desired fatty acids. Moreover, costly chemical steps are avoided and direct commercial use of these fatty acids is available. Among all microorganisms, the oleaginous yeasts have become the most promising hosts for lipid production - their efficient lipogenesis, ability to use various (often highly affordable) carbon sources, feasible large-scale cultivations and wide range of available genetic engineering tools turns them into powerful micro-factories. This review is an in-depth description of the recent developments in the engineering of the lipid biosynthetic pathway with oleaginous yeasts. The different classes of valuable lipid compounds with their derivatives are described and their importance for human health and industry is presented. The emphasis is also placed on the optimization of culture conditions in order to improve the yield and titer of these valuable compounds. Furthermore, the important economic aspects of the current microbial oil production are discussed.

BIO IOP A critical review on the economic aspects and life cycle assessment of biodiesel production using heterogeneous nanocatalysts

Esmaeili, H., *Fuel Processing Technology*, 230, 107224, 2022, https://doi.org/10.1016/j.fuproc.2022.107224

Rising global prices, increasing energy demand, and increasing greenhouse gas have led to the use of biodiesel fuel. Biodiesel fuel is a suitable alternative to diesel in diesel engines. Therefore, it is critical to analyze the economic aspects to decrease the cost of biodiesel production by finding more efficient catalysts as well as more suitable feedstocks. Therefore, this review paper focuses on recent findings of biodiesel generation from various oil sources using nanocatalysts. To this end, properties of various feedstocks and their oil content, characterization of various nanocatalysts and their ability in biodiesel production, life cycle assessment, and economic aspects of biodiesel production have been thoroughly studied. Also, several critical factors were studied on the economic feasibility of biodiesel generation, including various oil sources, type of nanocatalyst, the production capacity of the factory, the selling price of glycerol (by-product), the cost of land, labor cost, equipment, and alcohol type. Moreover, the cost of energy for biodiesel generation from various oil sources was investigated. The findings reveal that the use of CaO and MgO nanocatalysts and their derivatives decreases the cost of biodiesel production due to their simple synthesis, low-cost, abundance in nature, and high catalytic ability. Also, labor costs and plant production capacity have been indicated to have remarkable impacts on the biodiesel price. Moreover, the use of low-cost and non-edible oils with high oil content such as *Schizochytrium* sp. microalga and jojoba can significantly reduce the cost of biodiesel production.

BIO IOP Review of biodiesel production by the esterification of wastewater containing fats oils and grease (FOGs)

Ahmed, R. and Huddersman, K., *Journal of Industrial and Engineering Chemistry*, 2022, https://doi.org/10.1016/j.jiec.2022.02.045

A promising solution for the near future is the substitution of non-renewable fossil fuels with a sustainable liquid feedstock for biofuel (biodiesel) production. The cost of conventional biodiesel production is higher than that of petroleum-based diesel production since it is produced mostly from expensive high-quality virgin oil. 70–80% of the overall biodiesel production cost is associated with the cost of raw materials. Brown grease (with free fatty acid levels > 15%) is created from rendered trap waste and is known as Fats, Oils, and Greases (FOGs). It is a potential source of biodiesel feedstocks and is available at no cost. Many researchers are interested in using low-cost high Free Fatty Acid (FFA) oils as the feedstock for biodiesel production.

This paper reviews the effect of feedstock pre-treatment and process parameters on the conversion of FOGs-wastewater to biodiesel by esterification, including alcohol to oil molar ratio, reaction temperature, reaction time, catalyst amount.

EAT IOP Insight on zero waste approach for sustainable microalgae biorefinery: Sequential fractionation, conversion and applications for high-to-low value-added products

Cheirsilp, B. and Maneechote, W., *et al.*, *Bioresource Technology Reports*, 18, 101003, 2022, https://doi.org/10.1016/j.biteb.2022.101003

Microalgae, especially oleaginous species, have gained much attention as bioenergy feedstocks in response to uprising energy crisis, lessening natural resources, and climate change. Microalgae are also used to extract high value co-products such as pigments, vitamins, proteins, long-chain polyunsaturated fatty acids, and carbohydrates, those are beneficial in various sectors. These benefits authorize microalgae as a promising source for biorefinery. The focus on zero waste approach would help promote sustainability of microalgal biorefinery. This review offers depiction of evolving zero waste and biorefinery concept for the cost/energy-effective and maintainable processes. Sequential fractionation of microalgal biomass into promising raw materials for biorefinery access and recent conversion technologies applied on microalgal biomass, are discussed. The applications for high-to-low value added-products including nutraceuticals/pharmaceuticals, food and feed, bioenergy and biofuels, and fertilizer are proposed. Key challenges for zero waste microalgae biorefinery are summarized. These strategies may greatly contribute to sustainability of microalgae-based bioproducts and biofuels.

Original Articles

PRO IOP Formulation of silica-based corn oil transformed polyester acryl amide-phenol formaldehyde corrosion resistant coating material

Alam, M., *et al.*, *Journal of Applied Polymer Science*, 139, 7, 2022, https://doi.org/10.1002/app.51651

It is important to check the economic losses due to spontaneous metallic corrosion of major infrastructures, precious equipment's, and ensure the sustainable growth. Fabrication of environmentally benign functional polymeric material by transforming agricultural waste and products into value added polymeric products is of great importance in recent times. Here, we report the formulation of functional hybrid polymeric material using corn oil (CO) as our starting material. The functionality of CO was improved by green route, to produce corn diol fatty amide (HECA). Functionalization of CO was achieved in systematic manner by following green chemistry approach. First, diol fatty amide (HECA) was prepared followed by conversion of terminal OH groups of HECA into acrylic ester using condensation reaction with acrylic acid (AA). The base polymeric moiety was further modified to include phenyl acetylene functionality and SiO_2 nanoparticle entities. The formulation of hydrophobic stable polymeric structure is important to sustain highly corrosive environment and long-lasting performance of the material. The inclusion of different functionality and hydrophobic groups were confirmed by Fourier-transform infrared and proton nuclear magnetic resonance spectroscopies. The baked coating was finalized by addition of phenol formaldehyde polymeric resin in different phr (part per hundred part of resin). The transmission electron microscopy, scanning electron microscope, energy dispersive X-ray spectroscopy, and elemental mapping of the coating material confirms the formation of a hybrid material with uniform distribution of inorganic and organic components. The potentiodynamic polarization and electrochemical impedance spectroscopic analysis verified the better resistive performance of inorganic hybrid over the counter organic coatings. The enhanced thermal stability, hydrophobic character, and corrosion resistance performance of CO based coating material indicates the potential of the synthesized green route materials.

PRO PCP EAT Development of antioxidant peptides from brewers' spent grain proteins

Abeynayake, R., *et al.*, *LWT*, 158, 113162, 2022, https://doi.org/10.1016/j.lwt.2022.113162

Brewers' spent grain (BSG), the most abundant brewing by-product contains up to 24% (w/w) of protein on a dry basis but is used as low-value animal feed. This study was conducted to develop antioxidant peptides from BSG proteins. Protease hydrolysis significantly increased BSG protein solubility to 94.4%

at neutral pH. Peptides prepared by Alcalase, and its combination with Neutrase, Flavourzyme, or Everlase showed the highest DPPH radical scavenging activities ranging between 72.6 and 74.9%. The highest superoxide radical scavenging activity of 19.3% was observed in the hydrolysate resulted from Alcalase and Flavourzyme combination. Everlase and FoodPro PHT combined treatment was the most effective in producing ferrous ion chelating peptides. Molecular structures analysis suggests that histidine significantly contributed to DPPH radical scavenging activity of BSG peptides due to the high proton donation ability of its imidazole ring. Highly hydrolyzed BSG protein could have more positive charges to stabilize negatively charged superoxide radicals. Ferrous ion chelating ability was negatively correlated to degree of hydrolysis, suggesting that longer peptides are more likely to form compact structures to trap ferrous ions. This research has demonstrated the potential to use BSG as a cost-effective raw material to generate natural antioxidants for food applications.

S&D PRO PCP Ultrasound assisted *in-situ* separation of sophorolipids in multi-phase fermentation system to achieve efficient production by *Candida bombicola*

Chen, Y., *et al.*, *Biotechnology Journal*, 17, 2, 2022, https://doi.org/10.1002/biot.202100478

Sophorolipids (SLs) are regarded as one of the most promising biosurfactants. However, high production costs are the main obstacle to extended SLs application. Semi-continuous fermentation, which is based on in situ separation, is a promising technology for achieving high SLs productivity.

In this study, the sedimentation mechanism of SLs was analyzed. The formation of a hydrophobic mixture of SLs and rapeseed oil was a key factor in sedimentation. And the hydrophobicity and density of the mixture determined SLs sedimentation rate. On this basis, ultrasonic enhanced sedimentation technology (UEST) was introduced, by which the sedimentation rates were increased by 46.9%–485.4% with different ratio of rapeseed oil to SLs. UEST-assisted real-time in situ separation and semi-continuous fermentation were performed. SLs productivity and yield were 2.15 $g\ L^{-1}\ h^{-1}$ and 0.58 $g\ g^{-1}$, respectively, simultaneously the loss ratio of cells, glucose, and rapeseed oil were significantly reduced.

This study provides a new horizon for optimization of the SLs fermentation process.

H&N EAT Biophysical insights into modulating lipid digestion in food emulsions

Acevedo, A. and Singh, F. H., *Progress in Lipid Research*, 85, 101129, 2022, https://doi.org/10.1016/j.plipres.2021.101129

During the last decade, major scientific advances on understanding the mechanisms of lipid digestion and metabolism have been made, with a view to addressing health issues (such as obesity) associated with overconsumption of lipid-rich and sucrose-rich foods. As lipids in common foods exist in the form of emulsions, the structuring of emulsions has been one the main strategies for controlling the rate of lipid digestion and absorption, at least from a colloid science viewpoint. Modulating the kinetics of lipid digestion and absorption offers interesting possibilities for developing foods that can provide control of postprandial lipaemia and control the release of lipophilic compounds. Food emulsions can be designed to achieve considerable differences in the kinetics of lipid digestion but most research has been applied to relatively simple model systems and in in vitro digestion models. Further research to translate this knowledge into more complex food systems and to validate the results in human studies is required. One promising approach to delay/control lipid digestion is to alter the stomach emptying rate of lipids, which is largely affected by interactions of emulsion droplets with the food matrices. Food matrices with different responses to the gastric environment and with different interactions between oil droplets and the food matrix can be designed to influence lipid digestion. This review focuses on key scientific advances made during the last decade on understanding the physicochemical and structural modifications of emulsified lipids, mainly from a biophysical science perspective. The review specifically explores different approaches by which the structure and stability of emulsions may be altered to achieve specific lipid digestion kinetics.

IOP BIO PRO Heterologous synthesis and secretion of ricinoleic acid in *Starmerella bombicola* with sophorolipid as an intermediate

Chatterjee, M., *et al.*, *ACS Synthetic Biology*, 11, 3, 2022, https://doi.org/10.1021/acssynbio.1c00457

Ricinoleic acid (RA) is a long-chain hydroxy fatty acid produced from castor bean that is used in the manufacturing of a variety of industrial products. The demand for RA keeps increasing due to its broad applications. However, due to the presence of a potent toxin ricin, the native oilseed plant is not an ideal source for hydroxy fatty acid production. Although there have been significant efforts on engineering different microorganisms for heterologous production of RA, all had very limited success. The main reason for this is the exhibited toxicity of the intracellularly accumulated RA. To avoid this issue, we genetically modified a *Starmerella bombicola* strain by engineering its native sophorolipid production pathway to direct the synthesized RA bound with sophorolipid to be secreted out of the cell, followed by acid hydrolysis to recover RA. The engineered *S. bombicola* strain expressing the heterologous codon-optimized oleate hydroxylase-encoding gene from ergot fungus *Claviceps purpurea* resulted in a record production titer of RA at about 2.96 g/L. Thus, this work highlights a new strategy to produce a high level of hydroxy fatty acids in engineered yeast through a sophorolipid intermediate, enabling a new biocatalysis platform for the future.

EAT PRO PCP Cold plasma modification of food macromolecules and effects on related products

Kopuk, B., *et al.*, *Food Chemistry*, 382, 132356, 2022, https://doi.org/10.1016/j.foodchem.2022.132356

The food industry is in search of innovative processing technologies that are capable of providing food safety and improving quality with low processing costs and fast operations. As a new technique, cold plasma (CP) fulfills these requirements and thus gained significant attraction from researchers. Apart from general microbial inactivation purposes, CP can effectively modify the food macromolecules through reactions with reactive plasma species. In this context, this review focuses on the interactions between reactive plasma species and proteins, lipids, and polysaccharides. It also covers the changes in interfacial and mechanical properties of proteins and polysaccharides, effects on oleogels and xerogels, modifications in the allergenicity of proteins, and trans-free hydrogenation of oils. On the other hand, the concepts underlying the interactions between reactive plasma species and these macromolecules and the effects of processing parameters should be better understood, thus further studies should focus on these aspects.

LOQ H&N Recent developments on *Opuntia spp.*, their bioactive composition, nutritional values, and health effects

Daniloski, D., *Food Bioscience*, 101665, 2022, https://doi.org/10.1016/j.fbio.2022.101665

Opuntia is a plant that grows in wild, arid, and semi-arid regions, and it is a renowned food source that is presently undervalued. The chemical composition and properties of the *Opuntia* genus have attracted research and commercial interest as its species are rich in phytochemicals, nutrients, and bioactive compounds. Several of these constituents have revealed anti-inflammatory, antioxidant, antibacterial, anti-cancer, anti-atherosclerotic, antidiabetic, neurological, and gut protective characteristics. This review provides an extensive and up-to-date evidence synthesis of the nutrients in the *Opuntia* genus, its phytochemical composition, health benefits, the influence of the processing technologies on its bioactive components, and the potential for functional food product development. Due to its high nutritional value, *Opuntia* genus has the potential to contribute to improving food security and contribute to the food industry as food additive or preservative. Accordingly, *Opuntia* products can be utilized as food substitutes as part of a well-balanced diet and may potentially have pharmacological properties. The *Opuntia* genus is also used as animal feed, a source of nutraceuticals, an addition to edible packaging materials, wastewater treatment, and land rehabilitation in arid regions. *Opuntia* is a rich source of minerals, essential amino acids, and vitamins, and is high in antioxidants, making it a promising candidate for the management of non-communicable diseases. The potential health-promoting effects of *Opuntia* consumption remain relatively unexplored, and further research human trials are required to unravel its mechanisms of action.

EAT LOQ Effects of lipids with different oxidation levels on protein degradation and biogenic amines formation in Sichuan-style sausages

Liu, Y., *et al.*, *LWT - Food Science and Technology*, 113344, 2022, https://doi.org/10.1016/j.lwt.2022.113344

We evaluated the effects of different oxidation levels of lipids on protein degradation and biogenic amines (BAs) formation during Sichuan-style sausages processing. Lipids with varying degrees of oxidation were obtained through storage at different temperatures and added as raw materials of Sichuan-style sausages, followed by the analyses of lipid oxidation, protein degradation, biogenic amine content, and other indicators. During the processing, with increasing degree of lipid oxidation, the contents of peroxide value (POV), thiobarbituric acid reactive substances (TBARs), protein degradation index (PI), amino acid nitrogen (AAN), free amino acids (FAAs), and BAs increased. Based on the protein electrophoresis results, the higher the oxidation degree of pig backfat, the higher degree of sarcoplasmic protein oxidation, and the greater myofibril protein degradation. Pearson correlation revealed that lipid oxidation, protein degradation, and BAs content correlated significantly ($P < 0.05$).

EAT H&N Shelf life, physicochemical and antioxidant properties of red cactus pear *pulque* processed by ohmic heating and by conventional pasteurization

Alcántara-Zavala, A. E. and de Dios Figueroa-Cárdenas, J., *International Journal of Gastronomy and Food Science*, 100497, 2022, https://doi.org/10.1016/j.ijgfs.2022.100497

Red cactus pear *pulque* has bio-compounds and *Lactobacillus sp.* that confer functional properties. This beverage has a short shelf life (≤4 days) due to a high microbial load that causes its decomposition. Ohmic heating (OH) and conventional pasteurization (CP) are technologies for processing foods and beverages that contribute to preserving their quality. The aim of this study was to apply OH and CP for processing red cactus pear *pulque* in order to evaluate its effect on its microbiological, physicochemical, sensory, and antioxidant properties, and prolong its shelf life. Conditions at 60°C (for 8 min and for 10 min) and at 65°C (for 7 min and for 9 min) were used to process by OH, and CP was performed at 63°C for 30 min. Unprocessed beverage was used as a control. The shelf-life study was carried out of storing the samples for 15 days at 4 ± 1°C. Parameters such as pH, color, alcohol content, total soluble solids, *Lactobacillus sp.*, yeasts, polyphenols, betalains, and antioxidant activity were determined every 72h. The obtained results demonstrated that shelf life was prolonged for up to 12 days pre-

serving the physicochemical properties employing OH and CP. OH revealed better retention of sensory quality, a higher content of *Lactobacillus sp.*, betalains, polyphenols, and antioxidant activity than CP during storage. Best conditions for processing by OH were at 60°C for 8 min and for 10 min. *Lactobacillus acidophilus*, *L. kefiri*, and *Saccaromyces cerevisiae* were identified in red cactus pear *pulque* processed by OH.

EAT LOQ IOP H&N Characterization and incorporation of extracts from olive leaves obtained through maceration and supercritical extraction in Canola oil: Oxidative stability evaluation

Dauber, C., *et al.*, *LWT - Food Science and Technology*, 113274, 2022, https://doi.org/10.1016/j.lwt.2022.113274

Olive leaves (OL) are considered a potential source of bioactive compounds mainly due to its high content of phenolic compounds, widely known as natural antioxidants. The main objective of this study was to compare the performance of three OL extracts obtained by different extraction techniques in protecting canola oil against oxidative damage. The technologies evaluated were maceration with ethanol/water 75:25 (v/v), supercritical fluid extraction with CO_2 (SC–CO_2) and SC-CO_2 with 10% ethanol as modifier (SC–CO_2/EtOH). Each extract was analyzed as for total phenolic compounds (TPC), antioxidant activity (ABTS assay) and phenolic composition by reversed phase liquid chromatography-quadrupole-time of flight mass spectrometry. The oxidative stability of canola oil with or without the incorporation of 250 mg/kg of each extract was assessed during five weeks of storage at 60°C. Peroxide, K_{232}, K_{270}, and Rancimat values, besides tocopherols content were determined. Macerated extract showed the highest TPC and antioxidant activity, but both SC-CO_2 extracts were more effective in preserving tocopherols. In addition, SC-CO_2 extracts delayed the oxidation progress as they lead to higher induction periods than control and macerated extracts, and a slower increase in peroxide values. Results obtained reinforce the use of supercritical fluid technology to obtain antioxidants compounds from natural sources.

BIO The cultivation of five microalgae species and their potential for biodiesel production

Rodríguez-Palacio, M. C., *et al.*, *Energy, Sustainability and Society*, 12, 10, 2022, https://doi.org/10.1186/s13705-022-00337-5

Due to the problems we face today, such as wastewater pollution of aquifers and climate change, it is necessary to search for environmental solutions that help us minimize this problem. An alternative solution might be the cultivation of microalgae that are efficient in the purification of wastewater, removal of greenhouse gases and production of biomass that can be used for the production of biofuels such as biodiesel, methane, bioethanol, among others. The aim of this work is to cultivate five strains of microalgae native in Mexico: *Chlorella miniata*, *Coelastrella* sp., *Desmodesmus quadricauda*, *Neochloris oleoabundans and Verrucodesmus verrucosus*. The cultivations were performed using municipal wastewater and a foliar fertilizer with the further purpose of assessing their capacity to produce various types of biomass, in particular lipids.

The experiments were carried out using triplicate 16-L glass bioreactors assays with a 12:12 light–darkness cycle at 25°C ± 1 under constant aeration. Every 3rd day, a 1-mL sample was taken to determine cell density. In the stationary growth phase, each culture was harvested by sedimentation and lipid content analysis was performed. The biomass with the highest concentration of total lipids was subjected to an analysis of the methyl esters of fatty acids.

An ANOVA test showed significant differences between the growth rates ($F = 6.8$, $p = 0.0001$). The species that were able to produce biomass with the highest concentrations of total lipids were *Coelastrella* sp. with 44–46%; *Verrucodesmus verrucosus* with 43–44% and *Neochloris oleoabundans* 35–37%. As the analysis of the methyl esters of fatty acids showed, the species *Coelastrella* sp. and *V. verrucosus* produced lipids composed of 82.9% and 91.28% of fatty acids, respectively, containing C16–C18 carbon chains.

All the species used in the present study were able to grow on wastewater and produce high concentrations of lipids. Therefore, the demands for biodiesel production could be met in the immediate future after continuing working with different microalgae species. Therefore, it is necessary to determine their adaptation potential to grow on contaminated effluents and produce lipids that can be used for the benefit of people and environment.