

Milk Fat Membranes

Mimicking
mother's milk

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A close-up photograph of a baby's hands holding a white plastic baby bottle. The bottle has blue measurement markings on its side, including numbers 5, 4, 3, 2, 1, 150, 120, 90, 60, and 30. The background is a solid light blue color.

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Mimicking mother's milk

Stacy Kish

- The milk fat globule membrane (MFGM), which surrounds droplets of fat in breast milk, is a rich source of nutrients for infants, playing an integral role in brain and cognitive development. It also allows for the development of a robust immune system and healthy metabolism.
- Infant formula companies are exploring different techniques to enhance their product using components of MFGM to mimic the qualities and characteristics of breast milk. Clinical trial studies support the role enhanced formula play in an infant's growth and development.
- Companies are also exploring how the MFGM can improve the texture, composition and bioavailability of nutrients in foods, including butter and whipped cream.
- Future work may explore the role of MFGM in reducing frailty and improving muscle growth in older adults as well as reduce the harm from toxins produced by foodborne pathogens.

Food does more than deliver fat, protein, carbohydrates and vitamins to the body. The nutritional value of food is an interconnected web, a matrix. The food's structure affects how molecules interact and are absorbed. In fact, the food matrix is a more reliable way to evaluate a food's potential health benefits than simply considering each of the nutritional components alone.

"Molecules come embedded by nature in often complex, functional microstructures that we cannot see. Nutritional scientists aim to redesign some foods to protect nutrients and target them to perform specific functions in a way that may enhance human health," said José Miguel Aguilera, emeritus professor of chemical and food engineering at the Pontifical Catholic University of Chile in Santiago in an interview with BBC Food (https://www.bbc.co.uk/food/articles/food_matrix).

There may be no better example of this matrix effect than the milk fat globule membrane (MFGM), a tri-layer membrane that surrounds droplets of fat in breast milk.

CHALK FULL OF HEALTHY COMPONENTS

Milk fat globules range in diameter from 0.2 to 15 μm , far smaller than the width of a human hair. The MFGM that encloses this droplet of fat is even thinner. The membrane consists of a complex array of phospholipids and proteins arranged in three tiers (see image). The inner membrane is a monolayer of proteins and polar lipids obtained from the endoplasmic reticulum. The outer membrane is a double layer consisting of proteins and polar lipids originating from epithelial cells in the mammary gland. Sandwiched in between is a sheet of triglycerides (<https://doi.org/10.1016/j.jnutbio.2020.108465>).

While the MFGM accounts for less than 4% of total milk proteins, it contains a diverse collection of more than 500 different protein varieties. The MFGM is also rich in polar lipids, which provide the building blocks for cell membranes, the sheath (myelin) that covers nerves in the nervous system, and the production of lipoproteins, vitamin D and hormones. In addition, carbohydrates combine with the proteins or lipids to form glycoproteins or glycolipids that facilitate cellular recognition and signaling.

Breast milk is the gold standard for infant nutrition, offering the best path forward for an infant's growth and development. The MFGM perfectly encapsulates each milk fat droplet, preventing spoilage and aggregation. It also stabilizes the fat globule. The composition of the MFGM varies by lactation stage, season, fat globule size, maternal diet and even the collection method and time of day.



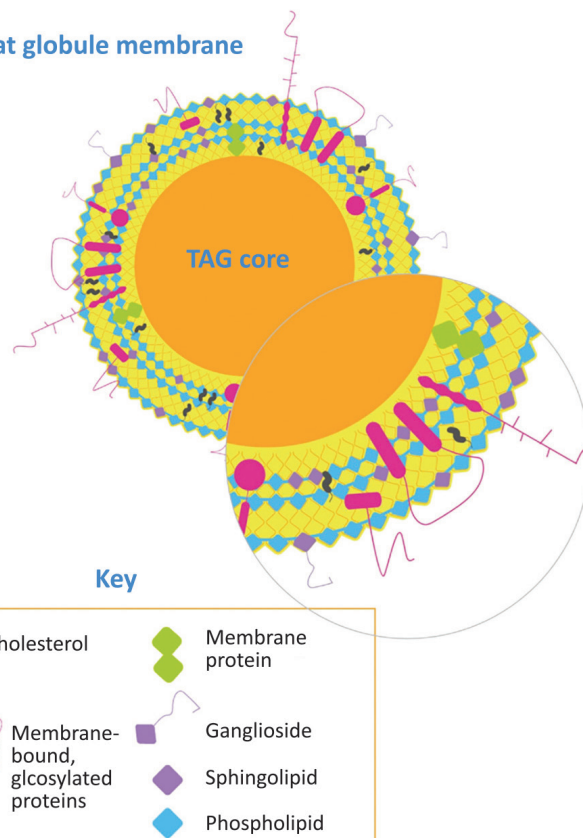
Despite the fact that breast milk promotes healthy growth and development, only a fraction of children worldwide receive this nutritional support throughout infancy. In the United States, less than a quarter of infants are breastfed after six months of age. Pre-term infants are at an even greater disadvantage, having also lost out on the growth and brain and lung development that occurs during the third trimester. Infant formulas provide an option for the sole or partial nutritional support for most infants during the first year of life, but infant formula is not a one-to-one replacement for breast milk.

Infant formula companies are working to address this nutrition gap and the market for this product is growing. The Global Infant Formula Oil and Fat Ingredients market size was valued at \$5,309 million in 2020 (<https://tinyurl.com/58kvm265>). It is projected to increase to \$5,650 million by 2027. The infant formula industry has been exploring how the different components of the MFGM can be used to create new lipid-based products that have similar properties as breast milk to ensure all children have the best start to their young lives.

REAPING THE BENEFITS OF THE MFGM

Infancy is a critical period for brain growth and development and early nutrition plays a key role in optimizing brain structure and function. While breast milk provides the most convenient form of nutrients to meet this need, infant formula enriched with bioactive nutrients provide a healthful and effective alternative. A recent study published in the journal *Frontiers in Nutrition* provides the first evaluation of the long-term impact of this early nutritional intervention (<https://doi.org/10.3389/>

Milk fat globule membrane



The complex, multi-layer structure of the MFGM, including key polar lipids and proteins. Source: Brink, L.R. and Lönnerdal, B., *J. Nutr. Biochem.*, 85, 2020.

fnut.2022.820224). The study enrolled infants and toddlers during the first 18-months of life. The children were then followed for six years to evaluate changes in their brain structures.

The study found infants fed formula enriched with MFGM, long-chain polyunsaturated fatty acids (LC-PUFA) and synbiotics (a mixture of prebiotics and probiotics) had neurocognitive outcomes and brain development that were similar to breastfed children at six years of age. The children fed the enriched infant formula scored higher in terms of IQ, vocabulary, and attention compared to their breastfed peers.

In addition, the children who received the enriched formula had greater brain volume and higher cortical thickness compared to children fed the standard infant formula. The researchers noted these changes in brain structure are related to improved cognitive development.

This study was unable to identify which of the three components (MFGM, LC-PUFAs and synbiotics) in the study were responsible for the observed improvements or if it was the result of a synergistic combination of all three.

Beyond the brain, the MFGM supports gut health. The intestinal tract of infants is a blank slate that is colonized through environmental exposure. These bacterial colonies play a significant role in the immune system to protect the infant from infection. Breast milk has evolved to help colonize the gut of infants with beneficial bacteria. Animal studies show how the MFGM modulates immune activities, offering protection from foodborne pathogens. Further, these studies have shown that gangliosides, molecules within the MFGM, inhibit production of *E. coli* enterotoxin, as well as cholera toxin by strengthening the barrier properties along the intestinal tract.

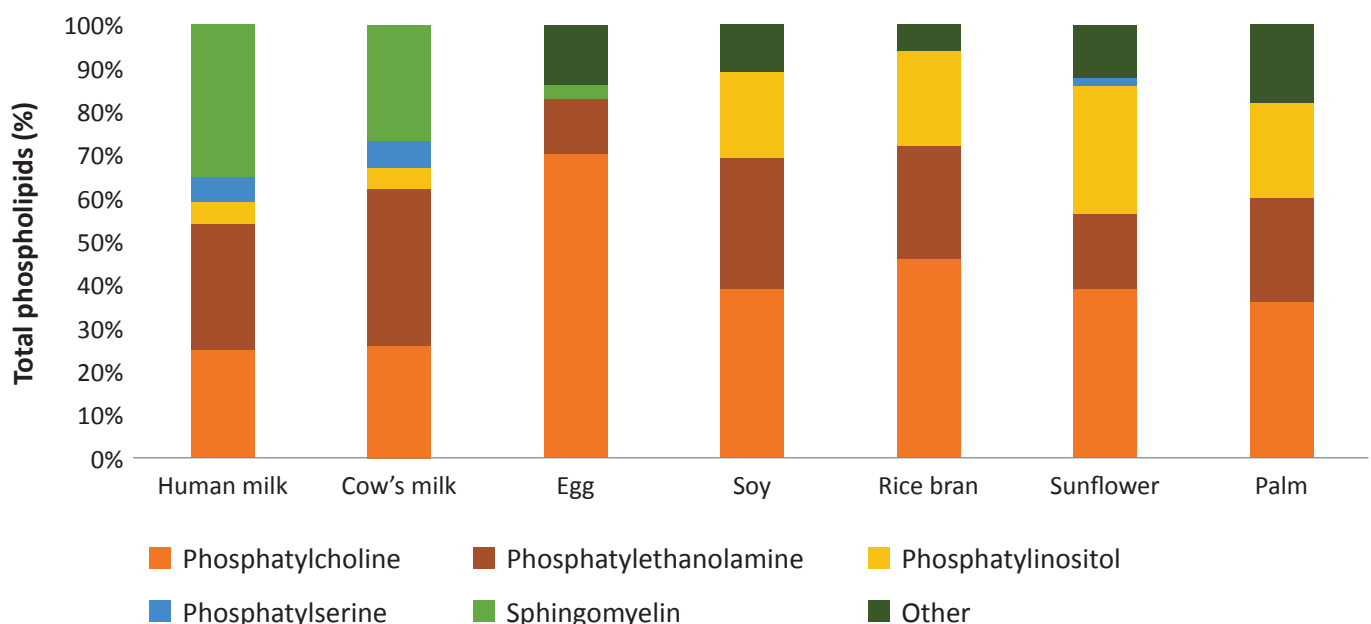
The MFGM also contributes to a healthy metabolism. Unlike standard infant formula, the MFGM in breast milk is high in cholesterol, and breastfed infants have a higher concentration of cholesterol that levels off throughout childhood.

Over time, breastfed children have lower incidence of cardiovascular risk, which points to the important role MFGM may play in cholesterol metabolism. Clinical trial studies point to the impact of MFGM-enhanced formula on higher serum cholesterol (HDL cholesterol and homocysteine) and higher serum choline compared to infants fed the standard formula. These results are more in line with levels found in breastfed infants. The study points to how these differences affect infant metabolism and long-term health.

ENHANCING FORMULA

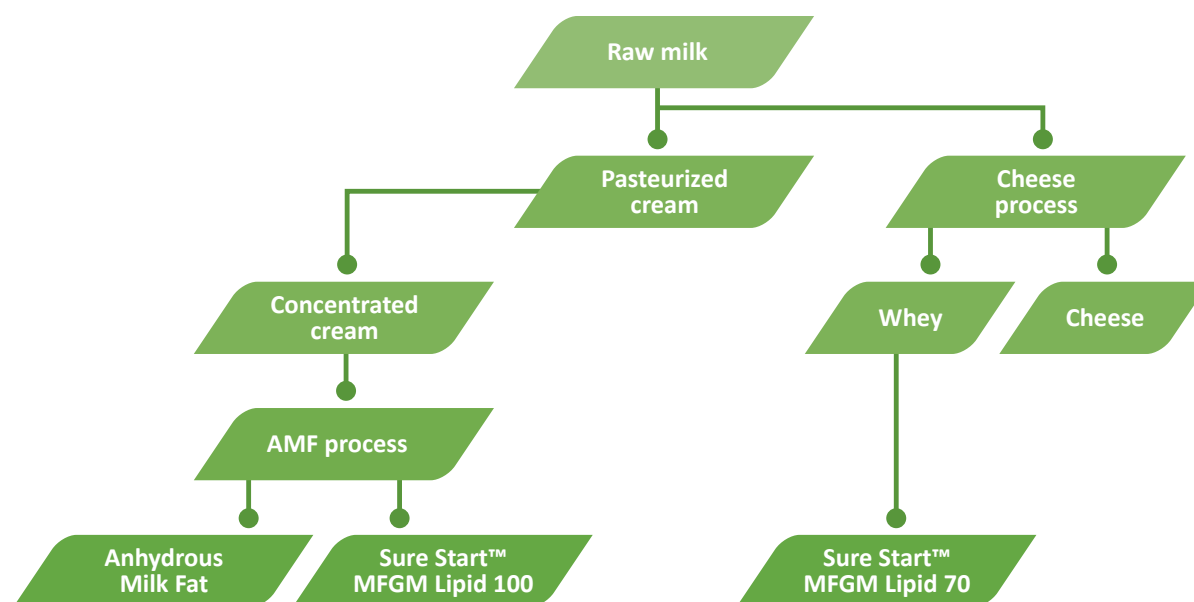
In recent decades, researchers have made progress creating better nutritional quality infant formula, and MFGM have played an integral role in these innovations. According to a 2017 study in the journal *Nutrients*, infant formula that incorporates the bioactive compounds found in MFGM may optimize the long-term health of the immune system and cognitive functioning of infants into childhood (<https://doi.org/10.3390/nu9080817>). Animal studies and human clinical trials support the role that MFGM play in cognitive and brain development.

The CLIMB (Complex Lipids In Mothers and Babies) study evaluated the outcomes of infants born to mothers who received complex milk lipids during pregnancy compared to those who received a standard maternal milk formulation (<https://doi.org/10.1136/bmjopen-2017-016637>). The researchers found prenatal maternal supplementation of gangliosides may improve brain development in the fetus. The CLING clinical trial assessed whether an enriched infant formula supports brain development as the children grow compared to infants fed a standard formula (<https://tinyurl.com/y336eura>). The study found that MFGM supplementation in early life improves some measures of normal cognitive development in infants, including higher cognitive, language, motor, social emotional, and general adaptive scores.



Human and cow (bovine) milk have a similar phospholipid composition. Both human and cow milk are more similar to composition of the human brain than other sources, like soy, egg or palm. The graph was developed using the work of Antonio Cilla and others in an article.

Source: Einerhand Science & Innovation



Fonterra manufactures MFGM-rich dairy streams from both the whey and cream components of cow's milk using two different processing routes. Source: Fonterra.

"This is one of the biggest revolutions in infant formula over the last several years," said Sandra Einerhand, founder and head of Einerhand Science & Innovation, a Dutch consultancy company that advises businesses on nutrition- and health-related questions (<https://esi4u.nl/about/>). "The MFGM market has not yet reached its full potential," she says.

Most MFGM found in infant formula is obtained from either the whey or cream concentrates from cow milk, which has a similar nutritional profile to human breast milk; however, different separation techniques affect the overall MFGM concentration gathered. While more research is needed to confirm the best approach and source material for new products, many companies are now exploring how to incorporate whey or cream MFGM into enhanced infant formulas that more closely resemble the nutritional profile and properties of human breast milk.

The New Zealand infant formula company, Fonterra, is a pioneer in the MFGM market (<https://www.fonterra.com>). It has created a MFGM lipid supplement, called Surestart™ Lipid, from the whey and cream components of cow milk. Using MFGM from both components provides the company greater flexibility in the formulation of their products. The company has focused on the role of complex milk lipids, especially on milk gangliosides, which play an integral role in the cognitive development of infants. Surestart Lipid has been shown to support fetal brain composition and infant cognitive development in several clinical trials.

Arla Foods, another pioneer in MFGM products, has created an array of food products, including Lacprodan® (<https://www.arlafoodsingredients.com>). This series of infant formulas use a dry blend protein, which contains a unique protein and lipid profile, including lactoferrin, IgG, sialic acid, phospholipids, and gangliosides. The product has been shown to have

antiviral and antibacterial mechanisms that support the colonization of the gut with healthy bacteria. Infants that are fed the enhanced formula have lower gut infections and reduced incidence of diarrhea episodes, which is particularly important for premature infants. Clinical studies have found that infants that have been fed formula supplemented with Lacprodan® MFGM-10 demonstrated improved neurodevelopment, improved behavior performance, and reduced stress-induced sensitivity (<https://doi.org/10.3390/nu12061607>). These infants showed changes in brain structure and higher serum cholesterol. This study was unable to determine the precise mechanism that leads to these benefits.

In the infant formula market space, Danone has created the product Nuturis® (<https://doi.org/10.1017/S0007114518001988>). The enhanced formula contains large phospholipid-coated lipid droplets isolated from buttermilk and butter serums through micro and ultrafiltration. The droplets in Nuturis® are larger (3–5 mm) than typical fat droplets in infant formula (0.4 mm) and mimic the structure of lipids in human milk. The larger droplet size has been shown to promote fat digestion.

A randomized clinical study examined the benefits of the larger fat droplet size on infant development. The study examined the outcomes of breastfed infants compared to infants fed Nuturis® or standard infant formula (<https://clinicaltrials.gov/ct2/show/NCT01609634>). It found the enhanced lipid structure in Nuturis® improved infant nutrition to support growth and body composition, which is more in line with the outcomes in breastfed infants.

THE FUTURE OF FOOD AND BEYOND

While the infant formula market may have the corner on MFGM, other industries are not far behind. Because MFGM

Techniques to harvest the MFGM

In 2015, Australian researchers developed a new, faster technique to separate milk fat globules for industrial applications. The system uses two fully submersible plate transducers contained within a large rectangular reaction vessel that can hold up to two liters of milk. The separation process begins when one plate emits a one- or two-megahertz ultrasonic wave that passes through the milk and reflects off the second plate. As the sound wave moves through the milk, it separates and concentrates the fat portion into the cream that floats to the top of the tank, while the remaining skim sinks to the bottom of the tank. The process takes only 20 minutes and is faster than traditional methods like natural fat sedimentation and buoyancy processing, which typically take six hours.

In an article for *Food Processing* magazine, the study author Thomas Leong, an ultrasound engineer and a postdoctoral researcher from the Faculty of Science, Engineering and Technology at the Swinburne University of Technology, in Melbourne, Australia stated, “These streams can be further fractionated to obtain smaller and larger sized fat globules, which can be used to produce



novel dairy products with enhanced properties.” Leong believes this process can create fat globules that can enhance the taste and texture of many products (<https://tinyurl.com/ypx5bwwt>).

contain both hydrophilic and hydrophobic components, it makes an excellent emulsifier to improve and texturize foods. Studies have found MFGM- and MFGM protein-based emulsions produced smaller droplets creating a liquid with a greater viscosity and improved stability. This approach offers the food industry a new way to enhance and transmit nutrients. For example, the bioavailability of beta carotene is low when it is found in an aqueous solution, but the bioavailability increases when beta carotene is contained in an emulsion.

Bhesh Bhandari, professor at The University of Queensland’s School of Agriculture and Food Sciences, in St. Lucia, Australia is pioneering techniques to create innovative dairy products by focusing on fat globule size. According to Bhandari, adjusting the size of fat globules in milk can produce different structures and textures in food.

Bhandari and his team are using existing dairy equipment with only minor modifications to prepare nano-emulsions, a technique developed by the pharmaceutical industry. The new process can manufacture functional cream powder to make whippable low fat cream that can be recombined with liquid milk, cheese, yogurt, and butter to make low fat butter and fat spreads.

“By tuning system parameters according to acoustic fundamentals, the technique can be used to specifically select milk fat globules of different sizes in the collected fractions, achieving fractionation outcomes desired for a particular dairy product,” said Bhandari, in a 2017 press release (<https://tinyurl.com/2p8mar6m>). “Our latest findings reveal that small fat globules impart an amazing stability to cream and give cold butter softer texture and improved spreadability.”

The MFGM also offer opportunities in the medical nutrition space as a medical food or as an oral nutritional supplement. Studies in healthy older adults suggest this product could strengthen muscle to prevent frailty. According to Einerhand, MFGM supplementation combined with regular exercise has been shown to improve skeletal muscle strength. Taking the data together, MFGM administration in combatting muscle loss and function at older age provides an interesting avenue for future studies. Einerhand says, the research completed to date have been small and used low doses of MFGM. In addition, the studies have produced conflicting and inconsistent results.

The role of MFGM in strengthening the barrier properties along the intestinal tract has also piqued research interest. The protective nature of MFGM against pathogens is particularly interesting after two long years of the pandemic. The protective property offered by MFGM provides an enticing path of study not only against viral agents, but also common bacterial pathogens, like *Clostridium difficile* and *E. coli*. MFGM research provides a ripe area of exploration for new products to reduce the incidence of respiratory or diarrhea-related illnesses in older adults or during extended hospital stays.

“MFGM lipid-containing products may have beneficial effects in adults, but clinical evidence is still quite preliminary,” said Einerhand. “The science needs to continue to evolve.”

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.

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From the lab bench to the executive suite

Angeliki Triantafyllou

In May 2021, the Swedish oat milk company, Oatly, was estimated to be worth \$10 billion after listing its initial public offering (IPO) on the United States-based NASDAQ stock exchange. The company's success marked the point when milk substitutes claimed their place as direct competitors alongside dairy, rather than fringe products. Most plant-based drink companies now include oat milk in their product line. Oatly's development started decades ago when biotechnology graduate student, Angeliki Triantafyllou, performed enzyme experiments on oat grains at Lund University. Here is her story.



addition, I had just started a family. The relative safety of answering a traditional job advertisement followed by recruitment into a large firm seemed more sensible than the uncertainty of self-employment. Yet, I was compelled by the excitement of exploring my own ideas.

Coincidentally, my husband at the time, Rickard Öste, a lecturer in the Food Chemistry & Nutrition Department at Lund, was discussing an oat surplus with the Southern Sweden Farmers' Cooperative. (The regional groups acted somewhat independently then, whereas now they have merged into a national cooperation.) Oats are one of a few good quality

crops that grow in the chilly, Nordic climate. The farmers were interested in finding a way to make oats more valuable beyond their traditional use as animal feed.

Sweden has a well-organized cooperative system for food and feed applications which takes care of all parts of the food chain from plant breeding and agriculture to energy and machinery (<https://tinyurl.com/4vd9e99f>). They also have a research foundation that facilitates the development of new ideas. Rickard had the idea to develop a cereal milk, a "Nordic soy milk."

CHOICE AND CHANCE

My career path was paved with a combination of talent, instinct, and little bit of luck.

After obtaining my first degree in chemistry from the University of Ioannina, in Greece, I had no idea what work I could do or would like to do. A graduate degree seemed the best path for acquiring the skills that would potentially allow me to be more competitive in the job market and to set my goals a bit higher. So, I attended Lund University in Sweden to pursue graduate studies in the Biotechnology Department.

Even in my final year of graduate school, as I prepared to defend my thesis, I was still uncertain about my path. Everything seemed possible and impossible at the same time. I thought someone seeking an academic career should be passionate about teaching. For me, that was not the case then. In

USING WHAT YOU KNOW

My specialization in enzyme technology was an excellent tool to transform the grain into a drink with pleasant taste and mouthfeel while keeping the healthy characteristics of the original material, primarily the physiologically functional beta-glucan soluble fibre.

Enzymes are nature's catalysts for numerous reactions with a range of applications in technical sectors, like pharmaceuticals and foods (<https://amfep.org/about-enzymes>). I worked in an inspiring laboratory where researchers investigated how to put this enzyme action to use. I experimented with hydrolase activity in low water systems to drive the equilibrium towards synthesis. Understanding the function of enzymes was paramount to choosing a suitable candidate and designing appropriate conditions for its action.

In addition, I worked hard to learn more about the chemistry and nutrition of the substrate—that is the grains, such as oat, barley, and rye. I also studied relevant products like soy-milk which is a traditional Asian by-product of tofu. Then I felt comfortable applying my knowledge to develop a new process.

Developing a process for manufacturing a new range of oat-based dairy products took place step-by-step. We were constantly evaluating the parameters and adjusting the conditions, since there are natural variations in both the enzymes and the substrate. This variability calls for continuous fine-tuning.

FINDING THE RIGHT PEOPLE

The journey to commercialize Oatly was very eventful and occasionally scary. A new company demands steadily increasing resources, like manpower and financing. The founding group must communicate their conviction for the project's value to a lot of stakeholders with different essential roles and competencies.

Financing a large volume, initially low profit food product takes resilience and patients. Although private investors may be interested in expansion plans after a product succeeds, we found it challenging to persuade them to join a high-risk project with no established market. Private investors have little time to learn about ideas they are not already acquainted with, and they have a short timeline for returns. Therefore, public and institutional funding were colossally important to us.

THE EARTH'S RESOURCES ARE LIMITED AND WE NEED INNOVATIONS TO SOLVE THE CHALLENGE OF SATIATING A GROWING POPULATION WITH GOOD QUALITY FOOD.

In Sweden, bureaucracy does not stand in the way of the entrepreneur. The government provides time and other benefits, such as personal ownership of the intellectual property (IP) rights. In that way, the company can endure, survive the high intensity development period, and eventually settle in the market.

In any case, entrepreneurship and self-employment calls for the pursuit of a strong belief in the project idea, for giving up personal time, and accepting the turbulence of unfolding events without breaking down. The entrepreneur must be interested in collaborating with different people. This open-mindedness is essential for good research to be transformed into a commercial application. Identifying the right collaborators and trusting competent people with essential parts of the work is imperative to increase the possibility of success.

Public and institutional investors initially helped finance Oatly. However, the investment and management teams changed throughout the years to accommodate the needs of the expanding company. Soon, the company had a more complex form with people involved beyond the founding group. The new team focused on reducing production costs and targeting messaging for the right consumers.





Angeliki Triantafyllou after receiving the Polhem Prize for the invention of Oatly brand oat milk. (Pernilla Pettersson photographer, <https://www.fotografpernilla.com>)

Our primary consumer group was the allergic and the extremely health-conscious who particularly needed such products. A massive acquisition of new consumers was possible when the trend of a healthy and sustainable diet became the new standard. That coincided, for good reasons, with the rise of social media.

ACHIEVING SUCCESS

Our new category of sustainable consumer product was initially popular throughout Sweden. In the early 2000s, we began selling in other parts of Europe. Then in the 2010s, our products became popular around the world, in part, because of Oatly's superior foamability compared to other milk substitutes.

We developed a patented enzymatic method to manufacture a more homogenous oat drink which we realized performed much better as a barista milk compared to other plant-based products. It foamed better and was more stable when mixed with hot, acidic coffee. In 2012, we appointed a new management team that (among other tasks) targeted sales to coffee shops. Oatly now has manufacturing plants in Sweden, the United States, the Netherlands and China and Singapore with more construction planned around the world.

Last December, the Polhem Prize—Sweden's oldest prize given by the Society of Engineers—was awarded to myself and to my former husband. The prize is named after a scientist, inventor and awarded to similar individuals whose innovations have achieved commercial success. I never imagined that my work would lead to such an honour. The acknowledgment

of the value of my day-to-day endeavour is an unmatched reward.

Oatly started out as a family project in the early 90s, that—through a predictably bumpy journey—evolved into an international company now publicly traded on NASDAQ. It has been amazing to be a part of this huge accomplishment. I feel humbled because I can see that the achievement is due, not only to hard work by people with many different competencies, but also to good timing and lots of luck. I have also experienced the stagnation of good projects for various reasons, and I know success is never a guarantee.

My experience working on Oatly taught me that I thrive working in a creative, pioneering environment. I am also passionate about discovering new ways to create healthy and resource-efficient nutrition. The earth's resources are limited and we need innovations to solve the challenge of satiating a growing population with good quality food. To achieve this, we must invest more in research and development. To support this initiative, I co-founded a new start-up company called Cerealiq that uses custom-made enzyme blends to produce functional, healthy foods and beverages.

The best advice I have for anyone who is uncertain about their career is: listen to your heart and try several routes before settling on one. There are no rigid job descriptions or designs nowadays. The career opportunities are immense, and they are all worth consideration.

Angeliki Triantafyllou has used her multi-disciplinary research experience in enzyme technology, functional ingredients, and nutrition to invent and commercialize sustainable food and drinks. She is currently running consulting companies like, DEONA, Aletrona and Cerealiq to support emerging food biotechnology ideas. She can be contacted at angie@cerealiq.com

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://fatsandoilrnd.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).



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.

Register today!

sustainableprotein.aocs.org





Food designers wanted

Khwanruethai Rawboon

- Newly industrialized countries are adjusting their economic models to catch-up with digitized global markets.
- Food designer is one of three careers that we identified as highly-skilled personnel that will be needed for the implementation of Industry 4.0 in these countries.
- Institutions of higher education must acknowledge imminent changes and foster appropriate skill development to prepare students for the digital workplace.

Technology links organizational processes and transforms industries by enabling real-time connections between humans, machines, and smart objects (<https://doi.org/10.3846/btp.2019.13>).

The internet of things, artificial intelligence (AI), cloud computing, autonomous vehicles, robots, and machine learning have converged to spark the fourth industrial revolution, also known as Industry 4.0 (<https://tinyurl.com/2p9xuzt9>). Currently, a gap exists between human resource capabilities and prospective industrial needs. However, studies on the key competencies required for crucial professions for Industry 4.0 are scant. We have identified the competencies necessary for a demanding career as a food designer in the future. Here, we make recommendations for universities to modify their curricula and for students to prepare themselves for the challenges and opportunities that will evolve over the next decade.

The term Industry 4.0 was coined in 2011, at a trade fair in Hanover, Germany, and subsequently adopted by the German government in 2013, as a strategic initiative to revolutionize the manufacturing industry. The suffix 4.0 indicates the current technological thrust as the fourth transformation in industrial production. Lately, Industry 4.0 has attracted increasing interest because of the discrete advantages it offers manufacturing organizations.

As a concept, Industry 4.0 describes a new phase of manufacturing operations that combine emerging and converging technologies to add value to the entire product life cycle (<https://doi.org/10.1016/j.ijpe.2018.08.019>). These novel technologies aim to offer improved conditions to workers to enhance productivity. Thus, humans and machines are considered an integrated socio-technical mechanism in the conception of Industry 4.0 (<https://doi.org/10.20965/ijat.2017.p0004>). (In 2019, INFORM magazine covered the topic of Industry 4.0 which has only seen accelerated implementation since the pandemic (<https://tinyurl.com/INFORMNovDec2019>)).

Governments within the European Union have prioritized Industry 4.0 by adopting large-scale policies to ensure inclusive growth that can create productive employment and decent jobs (<https://ec.europa.eu/growth/tools-databases/dem/>). Recently, Thailand has tuned its economic model to the world economy by announcing a new national innovation-driven economic development policy called Thailand 4.0. As a concept, Thailand 4.0 is closely related to the Industry 4.0 idea and is expected to lead Thailand out of the middle-income trap. It is designed to make Thailand a stable, wealthy, and sustainable economy in the dynamic global context.

However, the biggest challenge for newly industrialized countries, such as Thailand, Indonesia, Malaysia, India, Pakistan, Nigeria, and Brazil concerns the shortage of qualified technical and skilled workers (<https://doi.org/10.14716/ijtech.v9i3.1948> & <https://doi.org/10.29139/aijss.20170101>).

DIGITAL TRANSFORMATIONS

Change is faster and more unpredictable in the current global scenario. Enterprises and organizations must react very quickly to the challenges and opportunities presented by the business world. The implementation of emerging technologies is expected to bring certain transformations in social, economic, environmental, technical, legal, and political systems. Undoubtedly, lower-skilled workers confront becoming underemployed. Low-skilled and routine jobs will likely be replaced by automation and robots. In 2015, the management consulting group, McKinsey & Company, predicted that automation could displace 45% of the jobs currently performed by human labor and that technology would probably substitute 5% of the full-time jobs in the developing world. In 2016, the World Bank projected that 66.6% of the existing manual jobs could also be replaced by automation and robotics. The World Economic Forum tracked the labor market impact of Industry 4.0 and reported new roles that are likely to open at the forefront of the data and AI economy. This set of emerging professions reflects the continuing importance of human interaction in the new economy (<https://tinyurl.com/futurejobsreport>).

The ongoing COVID-19 pandemic has certainly fast-tracked digital transformation across all sectors. Digitalization has accelerated industry-based demands for a more skilled workforce. The challenge for employers concerns how they can ensure that their employees acquire the new skillsets a digitally transforming world demands.

To respond to this post-COVID era, the Thai workforce development agencies nominated the Office of National Higher Education Science Research and Innovation Policy Council (NXPO) to survey the demand for highly-skilled human resources and key functional competencies for 12 targeted industries. These industries include next-generation automotive manufacture, smart electronics, affluent medical and wellness tourism, agriculture and biotechnology, food for the future, automation and robotics, logistics and aviation, bio-fuels and biochemicals, the digital sector, medical services, defense, and education development (<https://www.nxpo.or.th/th/en/overview/>). They represent the business strengths of Thailand and will tether education and business with the Thailand 4.0 policy. In this manner, Thailand hopes to achieve economic prosperity, social well-being, increased human value, and environmental protection. We use Thailand's findings as an example of advisable educational focus for other newly industrialized countries.

FEATURE JOBS

The NXPO survey report revealed an existing demand for nearly 180,000 new graduates to serve in highly demanded positions in the country's 12 key industries: engineers, data scientists, technicians, developers, and marketing personnel. The survey also highlighted that the digital industry would tender the highest demand for personnel over the next 5 years. This sector will expectedly need a total of 30,742 workers, particularly 5,767 data scientists. Moreover, the robotics industry is projected to require 10,020 critical positions to be filled even though the country's robot production is still minimal and most of the robots used in Thailand are imported from countries such as Japan and Germany. However, the country's demand for robots continues to increase. Thus, the burgeoning robotics industry is estimated to demand 2,697 data scientists, 1,869 robotic control engineers, and 1,862 mechanical engineers. Meanwhile, the developing food industry sector will probably require 12,458 employees.

Thailand's current challenge is that its small- and medium-sized enterprises (SMEs) lack the requisite science, technology, and innovation capabilities. Their skill base must shift to more sophisticated, higher value-added activities. In addition, Thailand must foster innovation in research and development (R&D) and undertake economic initiatives to upgrade its technology, enhance organization, encourage innovation, and introduce new products.

The careers in highest demand, according to the Thai version of Industry 4.0 are robotics engineers, data scientists, and food designers. These careers are thought to represent the highly-skilled workers required for the industries with the most potential according to NXPO's report, hence, automation and robotics, the digital sector, and food for the future.

FOOD DESIGNER COMPETENCIES

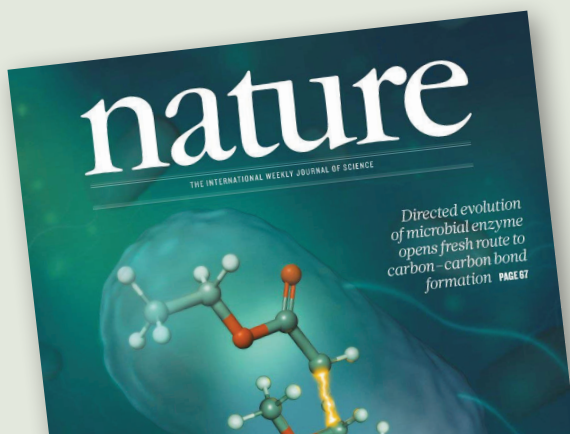
Food design is a recent discipline that includes designing research that generates new food-related products. This discipline forms part of industrial design by creating new food or

Career guidance survey

In 2019, *Nature* conducted a survey of PhD students and found a significant shift in their careers expectations. First, the survey found that graduate students were less likely to pursue a in academia compared to previous years. Openings for academic positions had dwindled leaving the students with no other option than to look elsewhere for their career. The second revelation gleaned from the survey was that students were not supported in their non-academic career searches. Since PhD advisors themselves have only experienced the trajectory of academia, they are often unable to guide students on any other path.

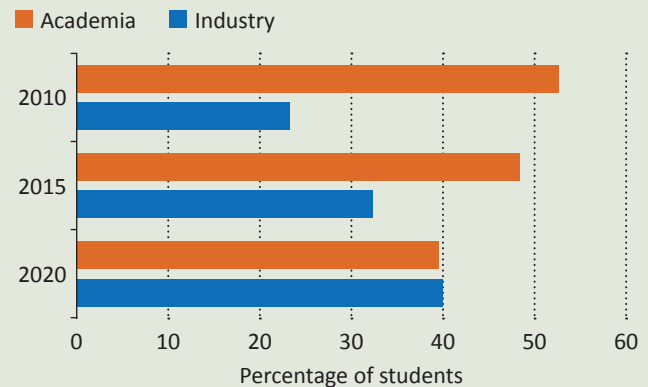
What can principal investigators do to assist their students? In a more recent *Nature* article four scientists shared this advice (<https://doi.org/10.1038/d41586-022-00162-y>):

- Have career-centered conversations with their students from the first minute they start in the lab and repeatedly throughout their programs
- Listen to young researchers; ask them what they want to do and what kinds of skills they want to develop
- Expose graduate students to people with non-academic careers so students grow their networks
- Organize a team video call every month with three people who have gone to work outside academia to demystify leaving the academic world



Results from a survey of PhD students who say they no longer find academic careers a viable option and they must be self-reliant in finding an alternative path.

Source: *Nature* 575, 403–406; 2019



How did you arrive at your current career decision?



new parts of complex food products. Food designers require the expertise to lead inventive projects from conception of an idea through the scale-up of a new product to quality improvements, value transformation savings, and production capacities for global operations. The role requires personnel to discover, develop, and apply new ingredient technologies for the creation of a more delicious, healthy, and sustainable future.

The essential competencies for food designers, as indicated by responses from experts in the “food for the future” sector, include the knowledge of the trends of food analytics,

food innovation thinking, food designing expertise, continuous learning, effective communication, and understanding the contexts of food. Experts recognized three of the competencies, namely the trends of food analytics, food innovation thinking, and food designing expertise, to be key determinants of the development potential of food designers.

An innovative mindset and knowledge of trends of food analytics are critical for discovering, advancing, and evaluating new technologies in food or for the processing of R&D initiatives toward the provision of innovative, timely, and cost-effective improvements to new or existing products or processes.

SOFT SKILLS ARE STILL IMPORTANT

Workplaces will become more complex and will involve personnel spanning multiple generations and nationalities. The management of varying time-zones, work patterns, and cultural attitudes given the impact of AI, and the coordination of divergent groups will become even more demanding than they are currently. Food designers should possess effective communication, active learning, adaptability to change, as well as leadership competencies.

With the increase in virtual work and globalized teams, communication skills are critical to help individuals persuade and inspire people toward the achievement of common goals.

Moreover, prospective workers must quickly assess situations and learn what they need to make effective decisions. Continuing to learn new things can broaden one's experience and provide a person with more potential opportunities. Hence, active learning is recognized as an important competency for future employees in the long term, especially for those open to novel opportunities. Such individuals may be accorded access to a variety of career paths in the future.

The ongoing, sweeping transformations introduced into societies due to digitalization make adaptability to change a critical competency for future employees who must respond quickly to changing trends, innovations, destabilizations, industry shifts, and other unforeseen circumstances.

Future employees in increasingly technology-driven and data-centered work environments will have to undertake more responsible tasks and take on more activities related to decision-making and data analysis. Thus, leadership skills are a recommended competency for every employee required to spearhead a team.

Finally, storytelling will become a commonly required competency for data scientists and food designers. Data scientists are extremely good with numbers; however, numerical skills are not sufficient on their own to convey outcomes of analyses to end users. Being a good data storyteller ensures that data analyses and modeling results are accurately and legibly transmitted to the appropriate audience. The practice and application of storytelling also helps food designers to create more compelling content to promote their businesses.

FINAL THOUGHTS

Asia is widely recognized as a hub that is pivotal for global economic growth. Therefore, the nations of this region must urgently explore crucial advanced technologies and changing competencies that could influence the future opportunities of university graduates. Mastery over new capabilities may accord a competitive advantage to the region's young graduates. A focus on capabilities including social, personal, and methodological abilities before leaving tertiary educational institutions can also open extensive opportunities for the region's graduates to compete with other, more experienced, candidates.

However, higher education institutions' training methods substantially influence students' abilities to develop competencies effectively. Hence, to ensure that this goal is reached, higher education institutions must brainstorm and investigate effective educational programs and methodologies to enhance the in-demand skillsets among its graduates and prepare them for future employment.

Industry 4.0, as previously reported, has resulted in a transition from a knowledge-based curriculum to competency-based instruction. Creating an intergraded curriculum that provides potential competencies, for example, would provide students with opportunities for advancement within the work system after they graduate and continue working in the field, as these skills train them to be forward thinkers, which promotes upward mobility.

As a result, combining the importance of hands-on pedagogy with competency-based education is in the long-term best interests of both students and employers, and a competency-based model would emerge as an effective teaching platform for producing professional potential learners. Furthermore, incorporating competency-based education is thought to increase active and immersive teaching approaches. Not only students but also teachers, appear to have more options to control their actions in order to attain learning goals.

Competency-based instruction should use instructional approaches that enable students to be self-directed learners, exercise what they have learned, and undergo educational opportunities that complement their learning style. Notably, this necessitates continued practice, as competency acquisition is always in a continuous phase.

The present study was conducted for three job positions projected to be in demand in Thailand: robotics engineers, data scientists, and food designers. Therefore, the results represent an overall perspective of crucial competencies for these three future careers in the digital era and hold true to a limited organizational sample. The context of additional careers could be explored by future studies, which could also focus in more detail on the additional aspects and challenges of the current dynamic world.

Khwanruethai Rawboon is a PhD student in the Graduate School of Engineering and Science at Shibaura Institute of Technology in Saitama, Japan. She was assisted by Atsuko K. Yamazaki, Wannaphop Klomklieng, and Wisa Thanomsub in the publication of this article. She can be reached at via email at nb18505@shibaura-it.ac.jp.

This article is an excerpt from the Journal of Competency-based Education article titled, "Future competencies for three demanding careers of Industry 4.0: Robotics engineers, data scientists, and food designers" and published here in accordance with the Creative Commons license.

2023 AOCS Awards Call for

Get ready – award nominations open June 1, 2022!



Society Awards

NOMINATION DEADLINE ► AUGUST 1, 2022

A.R. Baldwin Distinguished Service

Recognizes long-term, distinguished service to AOCS in positions of significant responsibility. The Society's highest service award. Sponsored by Cargill.

\$2,000 honorarium, \$1,500 travel allowance and a plaque

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.

Plaque and recognition during the AOCS Annual Meeting

AOCS Fellow

Recognizes achievements in science or extraordinary service to the Society.

Fellow membership status, a plaque and custom medal

Scientific Awards

NOMINATION DEADLINE ► AUGUST 1, 2022

Alton E. Bailey

Recognizes outstanding research and/or exceptional service in the field of lipids and associated products.

\$750 honorarium and a plaque

AOCS Corporate Achievement

Recognizes industry achievement for an outstanding process, product or contribution that has made substantial impact on its industry segment.

Plaque and recognition during the AOCS Annual Meeting

AOCS Young Scientist Research

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

\$1,000 honorarium, \$1,500 travel allowance and a plaque

Stephen S. Chang

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.

\$1,500 honorarium and a jade horse

Supelco AOCS Research

Recognizes outstanding original research in fats, oils, lipid chemistry or biochemistry. Sponsored by MilliporeSigma, a subsidiary of Sigma-Aldrich Corp.

\$10,000 honorarium, \$1,500 travel allowance and a plaque

Schroepfer Medal

Recognizes a scientist who has made significant and distinguished advances in the steroid field. Originated by colleagues of George Schroepfer.

Honorarium and a bronze medal

Division Awards*

NOMINATION DEADLINE ► AUGUST 1, 2022

ANA Division Herbert J. Dutton

Recognizes an individual who has made significant contributions to the analysis of fats, oils and related products.

\$1,000 honorarium, \$1,000 travel allowance and a plaque

AOCS Biotechnology Division Achievement Award

Recognizes a scientist, technologist or leader who has made contributions to the advancement of the Biotechnology Division's area of interest.

\$1,000 honorarium and a plaque

EAT Division Timothy L. Mounts

Recognizes research related to the science and technology of edible oils or derivatives in food products, which may be basic or applied in nature.

\$750 honorarium and a plaque

EAT Division Outstanding Achievement

Recognizes a scientist, technologist or leader who has made significant contributions to the Division's area of interest or to the advancement of edible oils.

\$500 honorarium and a plaque

H&N Division Ralph Holman Lifetime Achievement

Recognizes an individual who has made significant contributions to the Division's area of interest, or whose work has resulted in major advances in health and nutrition.

\$500 honorarium, \$1,000 travel allowance, a signed orchid print and a plaque

H&N Division New Investigator Research

Recognizes a young scientist who is making significant and substantial research contributions in one of the areas represented by the Health and Nutrition Division of AOCS.

\$1,000 honorarium and a plaque

Nominations

IOP Division ACI/NBB Glycerine Innovation

Recognizes outstanding achievement for research in new applications for glycerine with emphasis on commercial viability. Sponsored by the American Cleaning Institute (ACI) and the National Biodiesel Board (NBB).
\$5,000 honorarium and a plaque

PRO Division Distinguished Service

Recognizes and honors outstanding and meritorious service to the oilseed processing industry.
\$1,000 travel allowance and a certificate

S&D Division Samuel Rosen Memorial

Recognizes a surfactant chemist for significant advancement or application of surfactant chemistry principles. Initiated by Milton Rosen and this Division.
Plaque

S&D Division Distinguished Service

Recognizes outstanding and commendable service to the surfactants, detergents and soaps industry.
Plaque

Student Awards

NOMINATION DEADLINE ► OCTOBER 1, 2022

Honored Student

Recognizes graduate students in any area of fats and lipids. To receive the award, a candidate must remain a registered graduate student and must not have received a graduate degree or have begun career employment before the Society's Annual Meeting.

\$500 travel allowance for U.S. and Canada residents [\$1,000 travel allowance for recipients residing outside of those countries], complimentary AOCs Annual Meeting registration and lodging, and a certificate

Hans Kaunitz

Recognizes a student conducting research related to fats, oils and detergent technology.

\$1,000 honorarium, \$500 travel allowance and a certificate

Lipid Chemistry and Nutrition

Recognizes outstanding performance and achievement of a graduate student conducting research in lipid chemistry and nutrition. Sponsored by Seawit Co., Inc.

\$1,000 honorarium, \$550 travel allowance and a plaque

Lipid Processing and Biotechnology

Recognizes outstanding performance and achievement of a graduate student conducting research in lipid processing and biotechnology. Sponsored by Myande Group Co., Inc.


\$1,000 honorarium, \$550 travel allowance and a plaque

AOCs Division Student Awards

Recognizes over 20 students from any institution of higher learning, who are studying and doing research towards an advanced degree in fats, oils and related materials.

Awards range from \$50 to \$1,000 and a certificate

Please refer to aocs.org/awards for each award's specific nomination requirements.

 The award recipient must agree to attend the AOCs Annual Meeting & Expo and present an award lecture. The 2023 AOCs Annual Meeting & Expo will be held in Denver, Colorado, USA, from April 30–May 3, 2023.

*As of April 20, 2022. Award details subject to change.



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Recognition.
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Submission deadlines

Professional Awards ■ August 1, 2022

Student Awards ■ October 1, 2022

Travel Grants ■ December 18, 2022

Start a nomination or application today!

aocs.org/awards

AOCs 
Your Global Fats and Oils Connection

The next phase of diagnostics

Rebecca Guenard

Dogs know when a person has cancer by smelling the cellular changes indicative of tumors. Tumors shed biomarkers, such as nucleic acids, proteins, and metabolites that circulate through the body before being expelled in fluids or exhalations. A trained dog can detect lung cancer on a human's breath with over 95% accuracy. However, a canine is not ideal in a clinical setting. Researchers are instead teaching machines to have dog-like instincts when predicting human health outcomes.

- For decades, measuring biomarkers in the blood has been a reliable way to evaluate health and predict disease.
- Since most common diseases involve lipid-related disturbances, lipidomics is emerging as a valuable method for studying human health and disease prevention.
- With the application of machine learning, diagnostics are becoming even better predictors of impending negative health events.
- The future of diagnostics could be engineered, implanted sensors which boost biomarker signals that occur when the body begins to malfunction.

"Early detection typically saves a lot of lives," says Doug Bibus, president and co-founder of Lipid Technologies, in Austin, Minnesota, USA. "Treating someone who is just getting ill versus someone with an established disease makes a big difference, especially in terms of health care costs."

Globally, the leading cause of death is cardiovascular disease (CVD), accounting for nearly a third of all deaths worldwide. Experts estimate that trillions of dollars in health care costs and productivity loss could be recuperated if early detection reduced the incidents of CVD.

Bibus is part of a group of scientists who have been working for decades to provide analytical tools to better understand lifestyle choices that lead to chronic health conditions. By collecting drops of blood on paper cards, these diagnostic companies can establish a profile of an individual's health for clinicians to evaluate. His company measures health indicators like vitamin K, lipoproteins, cholesterol, even squalene resulting from traumatic brain injury, says Bibus.

Biomarkers are becoming popular sources for identifying new therapeutic targets and drug development, as well as signals for when to implement preventative nutritional strategies. Researchers are particularly interested in measuring inflammatory molecules and lipid profiles to someday reduce the widespread occurrence of Type 2 diabetes (T2D) and CVD. For cancer, bioengineered sensors that dwell inside the body could be a future biomarker detecting tool to prevent tumors from becoming invasive.

ANALYZING ESSENTIAL FATTY ACIDS

Dried blood spots provide a simple means of collection and storage for analyzing total blood lipids. Although hundreds of fatty acids are present in human blood, research has shown that data on the composition of a few essential fatty acids offers greater insight into an individual's dietary fat consumption patterns than questionnaires about food intake.

Over four decades, scientists have compiled data from thousands of blood samples. Fatty acids in blood and plasma are first converted to fatty methyl esters and then their concentrations are determined using gas chromatography and an internal standard (Fig. 1). These samples pro-

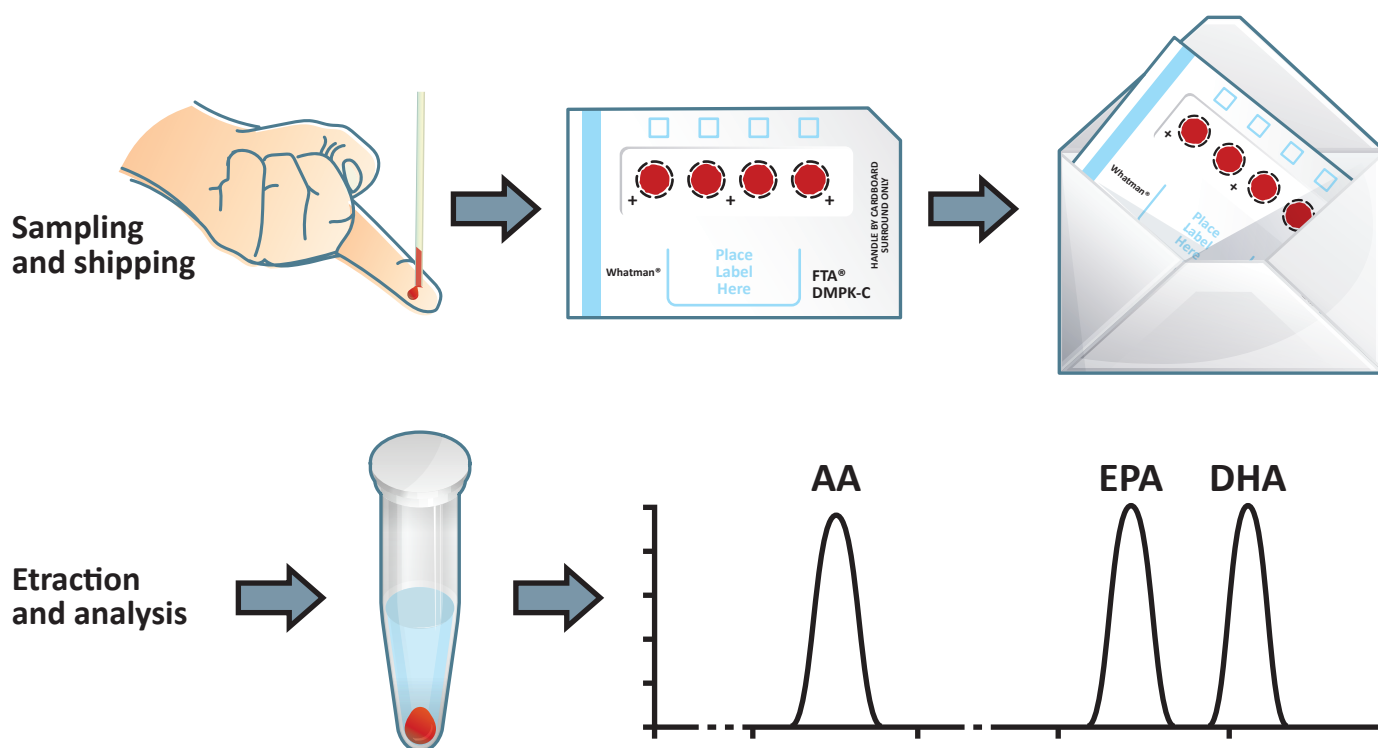


FIG. 1. The process of collecting and analyzing blood spots. According to Bibus this type of convenient, inexpensive microtesting has transformed the blood diagnostics industry.

vided the basis for a robust theoretical model used to predict disparities in human health (<https://doi.org/10.1194/jlr.D500022-JLR200>).

“We have done a lot of populational studies, looking at people from all over the world, and we saw significant differences in their omega-3 levels based on their diet,” says Bibus.

One blood sample analysis method proven to be a good indicator of fat consumption is known as the omega-3 index. The total concentration of two omega-3 fatty acids, EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), in a sample of blood is a useful biometric for a person’s risk of developing cardiovascular disease. People who eat more fish have higher levels of omega-3s and a lower chance of developing CVD, says Bibus.

A more in depth analysis compares omega-3 concentrations in whole blood samples with omega-6 values. Highly unsaturated fatty acids (HUFA)—C20 and C22 fatty acids with three or more double bonds—accumulate in tissue and reflect an individual’s dietary intake.

Bill Lands, a highly-decorated AOCS member and former biochemistry professor who is now retired from the University of Illinois, Urbana-Champaign, USA, realized the importance of measuring HUFA biomarkers. In particular arachidonic acid (AA), an omega-6 fatty acid involved in inflammatory processes in the body. It reacts with molecular oxygen through three different enzymes, leading to the generation of inflammatory bioactive lipids, known as eicosanoids.

Clinical research recognizes that many health conditions result when omega-6 mediators get too high. Lands established an equation that accounted for EPA, DHA, and AA (along with their C18 precursors) levels measured in blood spot assays to determine the percentage of omega-6 in a person’s blood.

“If you have a lot of arachidonic acid it is an indication of an environment fueling leukotriene production that causes inflammation,” Bibus says. “Eating omega-3s can effectively reduce your inflammatory response because the eicosanoids created from EPA and DHA are less potent mediators of inflammation.”

Bibus worked with Lands to predict healthcare costs based on omega-3 levels in blood. They found that the more omega-3 present in the blood the fewer health insurance claims a person made. “This model demonstrated that having a favorable omega-3 index paid off over time,” he says.

USING LIPIDOMICS

In a paper published in *PLoS Biology* this January, a German research team claimed they could predict an individual’s risk of type 2 diabetes and cardiovascular disease using lipidomics. The researchers, led by Chris Lauber, a computational virology professor at the Institute of Experimental Virology’s, TWINCORE, in Hanover, Germany, claim their analysis method is cheaper, faster, and more informative than current assessments based on clinical assays (<https://doi.org/10.1371/journal.pbio.3001561>).

First the team compared their findings to attempts at genomic analysis for type 2 diabetes and cardiovascular disease. In the early 2000s, significant research effort went into using genomics as a diagnostic tool. Genome-wide association studies revealed that genetic markers in different locations across multiple chromosomes all contribute a minor effect toward quantifying a person's risk for developing a disease. However, there are often too many small contributions for researchers to make a simple risk calculation and the use of genomics for diagnostics and healthcare has been limited.

Since most common diseases involve lipid-related disturbances, more researchers are applying systems biology to understand a lipid's function in an ever-increasing number of physiological roles where it is becoming apparent they are crucial. To catalog the extensive chemical and functional diversity of these molecules, the LIPID MAPS Consortium developed a classification system known as the LIPID MAPS database which

contains a list of more than 44,800 lipid structures (<https://www.lipidmaps.org/>). With the addition of analytical advancements for measuring lipids in biological matrices, lipidomics is emerging as a valuable method for studying human health and disease prevention (<https://tinyurl.com/2p849zdu>).

The experiments conducted by the German team are a prime example. The researchers used mass spectrometry to measure the molar concentration of 184 lipids in fasted blood plasma taken from a cohort of 4,067 individuals over 20 years. Using lipidomics, they identified a subgroup of individuals with significant lipidome differences at high risk of developing type-2 diabetes or CVD.

The most interesting result from the study was a comparison of lipidomics with results from genetics studies and standard clinical practice. There are 23 million single nucleotide variants associated with type-2 diabetes; of those, 19,214 are labeled significantly associated. For CVD there are 9 million

TABLE 1. Comparison of vital, clinical, genetic, and lipidomic variables. Future incidence of T2D or CVD for subgroup 6 was nearly 80% despite similar values for clinical measurements. Bold p-values highlight where results differ, primarily in lipidomic measurements. Source: Lauber, C., et al., *PLoS Biol* 20(3): e3001561.

parameter	type	mean subgroups 1 + 2 + 3 + 4 + 5	mean subgroup 6	log ₂ fold-change	adjusted <i>p</i> -value
age	vital	57.4	56.9	−0.013	0.309
male%	vital	0.389	0.435	0.159	0.335
BMI	vital	25.3	25.7	0.021	0.259
SBP	clinical	140.8	142.8	0.021	0.187
HDL	clinical	1.418	1.346	−0.075	0.007
LDL	clinical	4.158	4.251	0.032	0.260
TRIGL	clinical	1.253	1.349	0.107	0.064
FBG	clinical	4.898	5.021	0.036	0.001
HbA1c	clinical	4.798	4.793	−0.002	0.900
PRS	genetic	−0.178	−0.178	−0.0001	0.402
SM	lipid class	167.3	204.5	0.290	4.4 × 10^{−25}
CE	lipid class	5,774.2	4,952.2	−0.222	1.1 × 10^{−21}
LPE	lipid class	5.0	4.1	−0.315	1.2 × 10^{−21}
PE O-	lipid class	28.5	22.4	−0.350	2.7 × 10^{−21}
LPC	lipid class	142.8	170.8	0.259	5.8 × 10^{−18}
PE	lipid class	13.8	11.2	−0.299	1.8 × 10^{−10}
Cer	lipid class	6.5	5.7	−0.170	2.1 × 10^{−10}
Chol	lipid class	961.6	1,104.8	0.200	2.1 × 10^{−10}
PI	lipid class	37.6	40.7	0.113	1.6 × 10^{−04}
PC	lipid class	1,672.8	1,730.1	0.049	0.058
DAG	lipid class	26.9	28.0	0.055	0.336
PC O-	lipid class	61.8	60.6	−0.029	0.336
TAG	lipid class	1,278.6	1,288.3	0.011	0.836

BMI, body mass index; CE, cholesteryl ester; Cer, ceramide; Chol, cholesterol; DAG, diacylglyceride; FBG, fasting blood glucose; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; LPC, lysophosphatidylcholine; LPE, lysophosphatidylethanolamine; PC, phosphatidylcholine; PC O-, etherphosphatidylcholine; PE, phosphatidylethanolamine; PE O-, ether-phosphatidylethanolamine; PI, phosphatidylinositol; PRS, polygenic risk score; SBP, systolic blood pressure; SM, sphingomyelin; TAG, Triacylglycerol; TRIGL, triglyceride.

with 2,686 deemed significant. A participant labeled as genetically predisposed for these diseases actually only has about a 25% chance of that prediction being accurate. Since the lipidome changes over time, the team combined their findings with clinical measurements and increased the ability to predict disease from clinical data alone by over 50%.

The authors conclude their paper, saying: “The lipoproteins could indeed constitute extracellular lipid surveillance and delivery vehicles required to regulate metabolic homeostasis and make us, to some extent, independent of the diet that we consume, at least on short timescales. Lipid metabolism has the potential to be centrally involved in regulating cellular function. If this thesis is validated, lipidomics will be a convenient way to follow body metabolism.” If they are proved correct, pathological lipidome changes could trigger intervention years in advance of the onset of a major disease.

Of course, the predictive power of lipidomics would not be possible without the assistance of machine learning. Lauber’s team used measurements obtained from the study participants when they were healthy to teach computers to establish a model lipid profile. Machines can easily identify key features in complex biological datasets and pinpoint an unhealthy individual’s diverging results.

INTERNAL INDICATORS?


Diagnostics continue to push the timeline for detecting illness earlier and earlier with less invasive measures using biomark-

ers. Scientists are training computers to detect subtle changes in the body’s signals of health and disease to improve someone’s chances at a long life. The next step in this type of analysis is internal devices that amplify biomarker signals.

In the field of oncology, researchers are engineering genetically encoded components, like cells, that release synthetic biomarkers of a particular phenotype when triggered by an encounter with tumors. Internal diagnostic systems such as this can detect synthetic biomarkers before the tumor grows large enough to produce enough of its own biomarker to exceed the background signal created by bodily fluids. In addition, the phenotype specificity prevents false positives from healthy tissue (<https://www.nature.com/articles/s41568-021-00389-3>).

A similar device tuned to lipid analysis could warn patients of an imminent inflammatory cascade, prompting them to consider their recent lifestyle choices and make necessary adjustments. Bibus says, there is innovative technology on the horizon for many different healthcare issues that will make diagnostics more affordable and accessible for a larger population of people. Until such time, pay attention if your dog starts behaving differently around you.

Rebecca Guenard is the editor-in-chief of INFORM at AOCS. She can be contacted at rebecca.guenard@aocs.org.



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Enhancing the extraction of pumpkin seed oil

Tran Thi Hien and NguyenThi Minh

In 2013, the yield of pumpkin worldwide was 1797.19 thousand hectares, 137.3 quintal per hectare and 24.70 M tons (<http://faostat.fao.org>). According to the USDA National Agricultural Statistics Service, nearly 65,900 acres of pumpkins were harvested in the US in 2018, producing more than 1.5 billion pounds of usable pumpkins from more than 2 billion pounds produced (<https://tinyurl.com/4vjrxhny>).

- Research on pumpkin seeds show they contain beneficial phytosterols that assist the body with anti-inflammation, antioxidation, cholesterol reduction and cancer prevention.
- A number of methods for extracting oils from pumpkin seeds have been investigated, including mechanical compression, ultrasonic extraction, and microwave extraction.
- We were interested in discovering a method to produce a phytosterol-enriched oil
- A combination of enzyme and ultrasound assisted extraction resulted in the highest concentration of phytosterol in extracted pumpkin seed oil.

The countries with the highest volumes of pumpkin consumption in 2018 were China (7.9 M tons), India (5.9M tons) and Russia (1.3M tons) together accounting for 53% of global consumption, and the countries with the highest levels of pumpkin per capita consumption in 2018 were Ukraine (15.778 kg per 1000 persons), Iran (13.096 kg per 1000 persons), and Russia (8.784 kg per 1000 persons)..

Pumpkin seeds are used mainly in the rough form such as roasting and drying, however research shows pumpkin seeds contain valuable phytosterol which reduces cholesterol (<https://doi.org/10.1021/jf404955n>) and acts as an anti-inflammatory (<https://doi.org/10.1093/jn/138.3.476>), an antioxidant (<https://doi.org/10.1007/BF02976680>), and aids in cancer prevention (<https://doi.org/10.1038/ejcn.2009.29>). In Vietnam, one hectare of pumpkin produces 2000-2500 kg of pumpkin seeds, equivalent to 72-90 kg of pumpkin seed oil, or 110-140 kg of dried pumpkin powder, or 44.6-55.7 kg phytosterol

In our previous study, we produced a 78.1% oil yield from 100g pumpkin seed using an enzymatic extraction. A number of other methods for extracting oils from pumpkin seeds have been investigated, including mechanical compression (<https://doi.org/10.1016/j.indcrop.2011.03.009>), ultrasonic extraction (<https://doi.org/10.1016/j.jfoodeng.2006.04.020>), and microwave extraction (<https://doi.org/10.1016/j.lwt.2005.09.011>). Compared with traditional solvent extraction methods, ultrasonic extraction provides higher selectivity, is less time-consuming, has lower energy consumption and reduced emissions, and produces higher-quality oil (<https://doi.org/10.1016/j.enconman.2011.11.005>). We investigated the effect of combining ultrasound and enzymatic oil extraction focusing on the enrichment of phytosterol from *C. pepo* seeds harvested in Vietnam.

Ultrasound assisting reduced the extraction time from 6 hours to 3 hours at the conditions investigated (see our paper, <https://doi.org/10.30721/fsab2021.v4.i1.104>). The resulting oil yield was $93.17 \pm 0.1\%$ for the 1st extraction. Under the same conditions, a second extraction for 1.5h gave $2.29 \pm 0.02\%$ oil yield. This means the yield of two replications of extraction was 95.46% and in 100 ml obtained oil there were 2017.5 mg of phytosterol extracted.



We also studied the effect of pumpkin seed treatment with the enzyme alcalase, prior to extraction. Alcalase assisted extraction showed that yields did not increase beyond an extraction time of four hours. After alcalase hydrolysis, we performed a pumpkin seed extraction twice and obtained a total oil yield of $89.65 \pm 0.11\%$ with 1992.7 mg phytosterol in 100ml of oil.

Finally, alcalase assisted extraction was improved by ultrasound. We hydrolyzed pumpkin seeds using alcalase and extracted at 40 kHz of ultrasound. The oil yield was $85.08 \pm 0.01\%$ after 3hrs and did not increase with longer extraction durations. Two extractions by enzyme and ultrasound assisted extraction gave a total oil yield of $91.87 \pm 0.03\%$ and the phytosterol content was 2327.7 mg in 100 ml oil.

The comparison of all extraction methods are presented in Table 1. The oil yield and phytosterol content in the oil obtained from the ultrasound assisted extraction (UAE) were $95.46 \pm 1.00\%$ with 2017.5 mg phytosterol per 100ml oil. These amounts were higher than those obtained from hexane extraction by roughly 5.39% oil and 359.9 mg phytosterol per 100 ml oil. The phytosterol content in oil extracted through

a combination of enzyme and ultrasound assisted extraction produced the highest yields (2327.7 mg phytosterol per 100 ml oil) compared to the three other extraction processes. For *C. pepo* seeds, oil extraction was most efficient using UAE, while the phytosterol extraction was most efficient with an enzyme and ultrasound assisted extraction (E_UAE).

In conclusion, for industrial practices we recommend E_UAE when extracting pumpkin seed oil with the intention of enriching phytosterol.

Tran Thi Hien and Nguyen Thi Minh Tu are associated with the School of Biotechnology and Food Technology at Hanoi University of Science and Technology in Vietnam. Nguyen Thi Minh Tu can be reached at via email at tu.nguyenthinh@hust.edu.vn.

*This article is an excerpt from a Food Science and Biotechnology article titled, "Enhancing the extraction of pumpkin seed (*Cucurbita pepo* L) for increasing oil yield and its phytosterol content" and published here in accordance with the Creative Commons license.*

TABLE 1. Comparison of phytosterol amounts after performing four different pumpkin seed oil extraction methods: solvent extraction (SE), enzyme assisted extraction (EAE), ultrasound assisted extraction (UAE), and enzyme and ultrasound assisted extraction (E_UAE). For experimental conditions refer to our research paper (<https://doi.org/10.30721/fsab2021.v4.i1.104>).

Extraction Method	Extraction Time (hrs)	Oil yield from two extractions (%) (% after 1 st extraction)	Phytosterol (mg/100 g seeds) using UV-Vis spectroscopy	Phytosterol (mg/100 ml oil) using UV-Vis spectroscopy
SE	7.5	90.07 ± 0.17 (87.59 ± 0.51)	642.2 ± 32.1	1657.6 ± 82.9
EAE	6	89.65 ± 0.11 (83.21 ± 0.10)	736.6 ± 36.8	1992.7 ± 99.5
UAE	4.5	95.46 ± 0.06 (93.17 ± 0.01)	794.1 ± 39.4	2017.5 ± 100.1
E_UAE	5	91.87 ± 0.03 (85.08 ± 0.40)	881.7 ± 41.8	2327.7 ± 110.4

Giants of the past: Albert Jan Dijkstra (1939-2022)

Marc Kellens

If you have spent any time on inform|connect then you know Albert Dijkstra. Since its inception, Albert contributed regularly to the platform. His posts reflected the decades of experience he had in the fats and oils industry. He sometimes lamented modern adjustments to the strict discipline of a bygone era of science. But he did it as a true scientist, by presenting a hypothesis and inviting colleagues to offer evidence to the contrary. Above all, he was exceedingly helpful. There was rarely a question for which Albert failed to offer an insight that might unravel the solution. Albert passed away March 15th, and his contributions to inform|connect and AOCS will be greatly missed. Here one of his associates reflects on his contribution to oils and fats science.



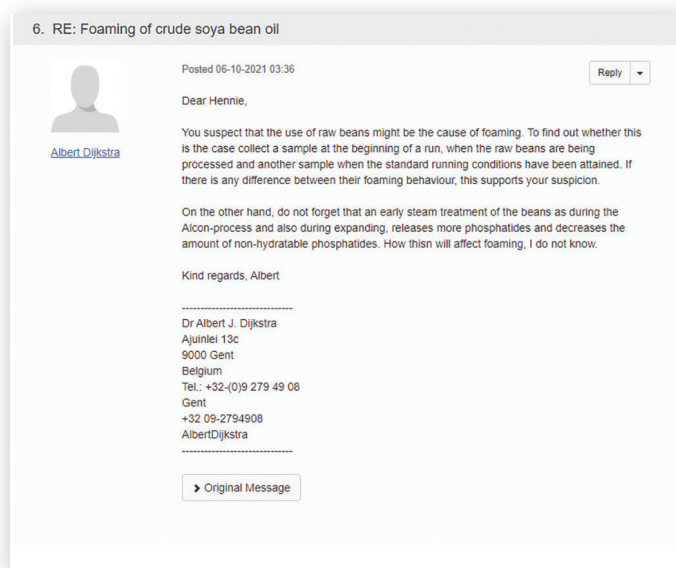
The last time I met with Albert was on March 4th. When I entered his room in the hospital in Ghent, Belgium, Albert was busy embroidering a rendition of a Cornelis Jetses painting titled, “De Schelpenvissers” (the shell fishermen, see picture). He told me it is quite big and complicated. He wondered if he would live long enough to finish it, but that did not bother him because the embroidery itself was a soothing distraction. He was also working on a book about the Arraiolos embroidery technique—a type of cross-stitch with wool thread on linen or jute fabric used to make rugs and tapestries since the 12th century. Albert had a proposal for technical upgrades which clearly improved the visual quality of the technique. Typical Albert, always eager to question and then improve.

I have known Albert since 1984, for almost 40 years. The first time I met him was during an interview at the University of Leuven, Belgium where he was setting up a project to study the crystallization behaviour of fats and oils. It was a tough interrogation. I left the interview concerned about what I knew and did not know, but I was selected.

Albert helped me to get my PhD and was later my boss. My first job in the oils and fats industry was in Albert’s R&D facility at the Vandemoortele Group—a Belgian-based, leading European food group that manufactures and sells high-quality food products, like frozen bakery products, margarines, and culinary oils and fats.

I left Vandemoortele Group in 1991, to join De Smet Group and remained in contact with Albert. Our professional





“ALBERT’S CONTRIBUTIONS WERE ALWAYS SOUNDLY GROUNDED IN SCIENTIFIC AND ENGINEERING FUNDAMENTALS AND SHOULD SERVE AS A MODEL FOR NEWCOMERS TO THIS FIELD.”

roads crossed again, when he retired in 1997, and became our intellectual property consultant. He became a well-known and respected scientific consultant in the oils and fats processing industry. Over the years, we have had invaluable discussions on how to improve the quality of oils and fats. We talked often about how to make processes more efficient by redesigning them or developing new ones, always with a Dutch touch of innovation.

Albert was born and educated in the Netherlands. His hometown is Rotterdam, but he earned his chemistry degree from Leyden University. He studied gas kinetics for a year at University College Wales in Aberystwyth, United Kingdom, before returning to Leyden University for his PhD.

Albert started his career in 1966, at Imperial Chemical Industries (ICI) in Runcorn, UK. During his ten years with the company, he started out as a chief chemist in the fibres section of ICI Holland in Rozenburg, the Netherlands, followed by a promotion to new product development leader of ICI Europe in Everberg, Belgium.

Before he eventually got involved in oils and fats, he made a 2-year stopover, from 1975 to 1977, as senior market researcher for Charles H. Kline in Brussels, Belgium. In 1978, Albert became the R&D director of the Vandemoortele Group, where he set up a completely new facility, integrating fundamental science and applied technology. Sharing his knowledge with many others in the oils and fats field was in his DNA. The same goes for his critical view of products and processes with the aim of making them better and more efficient.

In his long career, Albert received numerous awards for his contributions to the oils and fats industry. He was an active member of several societies, but especially AOCS.

“Albert’s contributions to our better understanding of lipid chemistry and processing are legendary,” says Keith Meyers, who is retired from Kraft Foods. “They were always soundly grounded in scientific and engineering fundamentals and should serve as a model for newcomers to this field. He was a superb, prolific, and conscientious author, always willing to share his knowledge and insights in books, journals, and on-line.”

“Albert was a source of great information to many people,” said Laurence Eyres of ECG consultants in Warkworth, New Zealand.

His contributions and achievements to the oils and fats industry are indicated by the many awards he has received, including several from AOCS. He was granted the Alton E. Bailey Award, the PRO Division Distinguished Service Award, the Stephen S. Chang Award, and the Timothy L. Mounts Award. In addition, he was named an AOCS Fellow in 2010, and Emeritus member in 2020.

He wrote the processing chapters in *The Lipid Handbook*, 3rd Edition, and his book, *Edible Oil Processing from a Patent Perspective*, is available through Amazon. The bulk of the book dissects processes and applicable patents, and provides a unique perspective into the industry, particularly post-1990. He was also a co-author on the book *Trans Fatty Acids*. His work on enzymatic degumming is at the foundation of all scientific and practical approaches to this essential process in the industry.

He has around a dozen patents to his name, covering various technical areas. Just for something different, he translated the original magnus opus on oils and fats by Chevreul from French into English. Chevreul’s fame as a lipid chemist culminated in 1823, with the publication of his research on animal fats in which he unravelled the nature of the saponification reaction and demonstrated that fats and oils are esters of fatty acids and glycerol.

With over 50 years of professional careers in various fields, many people knew Albert and his dedication to science. He had his own way of presenting new theories and facts, challenging everyone and everything he did not agree with 100%. The objective was always to teach and share his knowledge with everyone. Albert was a very science-oriented person and an excellent chemist.

When I visited Albert in the hospital, we talked for a long time about the past, present, and even the future. He explained to me the ideas he still had for improving various oil refining processes or unmasking the chemical nature behind the common contaminants in an oil. A creative personality and a problem solver to the end.

Albert was a brilliant man with an original wit and many talents. He was a pure scientist in heart and soul. Above all, Albert was a really nice guy. We will miss him, but he will be remembered.

To use Albert’s favourite Latin expression when closing a presentation: *dixi*, I have spoken.

Marc Kellens is the global technical director of De Smet Ballestra group. He can be contacted at MKellens@desmetballestra.com

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

Biologics—pharmaceutical products isolated from natural sources and modified—are changing the way we do medicine. With high specificities, low toxicity, and limited side effects, biologics have revolutionized the treatments of anemia, cancer, and various other autoimmune diseases. According to analysis by *Reports and Data*, the global biologics market was valued at \$324.78 billion in 2020 and is expected to rise to \$749.62 billion by 2028 (<https://tinyurl.com/4rvpnxjh>).

The nature of biologics as derivations of biological organisms, though, creates a few common problems. They often have high immunogenicity, meaning that biologics-based treatments oftentimes provoke unwanted immune responses in patients. Additionally, these biological agents frequently have very short half-lives as they are processed in the body.

One growing limb of biologics is the incorporation of non-standard amino acids (nsAA) into proteins. By synthetically expanding the standard 20-amino-acid palette, we can create a range of proteins and biopolymers with new chemical and biophysical functions. To date, work on nsAA has been limited to one or a few site-specific incorporations per protein, but recent advances in mechanisms and processes have laid the groundwork for more effective use of nsAA (<https://doi.org/10.1038/nbt.3372>).

For protein and peptide pharmaceuticals, nsAA are an attractive option in attempts to enhance functionality. They



are highly active, and in peptides, can help rapidly penetrate the patient's tissue.

Unfortunately, a few major roadblocks currently prevent extensive use of protein and peptide-based pharmaceuticals: they must be administered by injection, and they are rapidly cleared by kidneys and broken down by enzymes. Thus, patients using protein and peptide-based treatments must take frequent, high doses of the medicine, leading to a “peak and valley” pharmacokinetic profile. This can lead to reduced

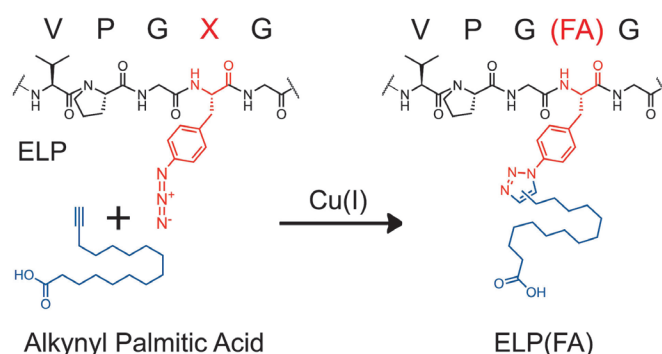
patient compliance and can even trigger an immune response that nullifies the pharmaceutical benefits of the treatment (<https://doi.org/10.4161/self.1.4.13904>).

To combat the issues raised by these short half-lives, many have turned to one nsAA, poly(ethylene glycol), or PEG, which, when incorporated into a protein or peptide chain, extends the radius of the product. This thereby reduces proteolytic cleavage and clearance by the kidneys, ensuring that the pharmaceutical stays active in the body for much longer (<https://doi.org/10.1038/nrd1033>).

In spite of the process' widespread use, some researchers have raised concerns about PEGylation. It has been demonstrated that the immune system can produce antibodies which specifically bind PEG, leading to accelerated blood clearance of PEGylated therapeutics (<https://doi.org/10.1002/wnan.1339>). Additionally, PEG can accumulate in the body; in mice, PEG was shown to build up in muscle, skin, bone, and the liver (<https://doi.org/10.002/jps.2600830432>).

It is thereby necessary to design alternative nsAA and incorporation procedures, especially considering that PEGylation does not universally have the desired effect on pharmacokinetics for all proteins and peptide chains. One effective option is the use of fatty acids (FA) attached to special nsAA to promote binding to serum albumin, a protein generated by the liver which is present in the blood. FA have a clinical precedence—they have been used in the treatment of diabetic patients, where insulin and glucagon-like peptide-1 are conjugated with a FA—and have a well-established safety profile (<https://doi.org/10.1021/jm9909645>).

In a recent article, Koen Vanderschuren of Yale University addressed a key difficulty with the use of FA conjugation in biologics: the need to precisely modify a protein while maintaining bioactivity (<https://doi.org/10.1073/pnas.2103099119>). Conventional strategies for fatty acid incorporation typically modify the target protein at its termini or at residues with reactive side chains. While this makes protein functionalization



Biopolymer functionalization with alkynyl palmitic acid using a non-standard amino acid. Source: Vanderschuren, K., et al., *Proc. Natl. Acad. Sci.*, 2022.

highly selective and predictable, it can come with the undesired side effect of reducing bioactivity. Furthermore, past approaches have only included a single addition of a nsAA per protein.

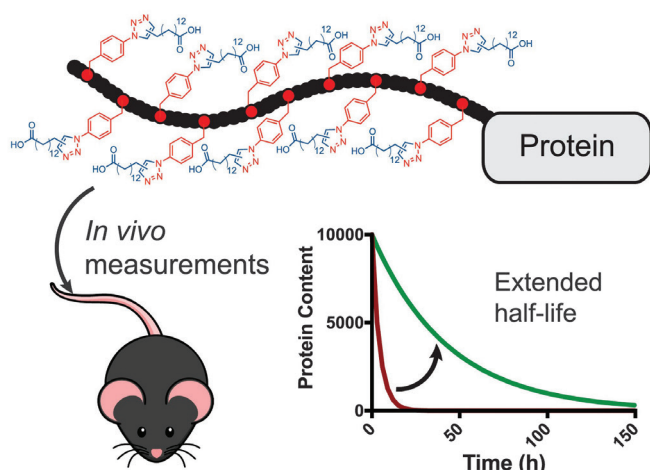
The incorporation of one nsAA constrains the versatility and tunability of functionalized peptides and proteins. To combat this, Vanderschuren and his team created a synthetic biology platform in which multiple nsAA may be added to a protein or polymer, tailoring the increase of the selected biopolymer's half-life in vivo.

The researchers used the nonstandard amino acid *para*-azidophenylalanine (pAzF), which they encoded in elastin-like polypeptide fusion proteins. Once a pAzF has been embedded, a fatty acid can be attached to its end (they used, alkynyl palmitic acid). Up to ten of these FA were included in each protein, and their position and number could be precisely controlled. The number of FA per protein were strongly correlated with the binding affinity to serum albumin, which enabled the researchers to tune the in vivo half-life of proteins by adjusting the amount of FA.

In the study, the bioactivity of the synthesized polypeptide polymers was not significantly lessened, and in mice, the functionalized biopolymers were biocompatible and did not elicit inflammatory responses.

In order to determine the biocompatibility of the synthesized proteins, the researchers studied the biodistribution and presence of inflammation in mice injected with the biopolymer. One group was given the protein without any added fatty acids; the other group was given the modified protein with 10 fatty acids. After 48 hours, only the protein with fatty acids attached was detected in the blood; neither protein could be detected in the organs. These results indicate that there is no risk of buildup, as there would be with PEGylation; additionally, there was no inflammation.

The advances made by Vanderschuren and his group may be the first stepping stone to a new era in biopharmaceuticals. Using FA to systematically increase the half-life of proteins and biopolymers they have shown it is possible to optimize both the pharmacokinetics and bioactivity of future drug candidates.



Researchers showed they could tune a biopolymer's half-life in vivo by functionalization it with a fatty acid Source: Vanderschuren, K., et al., *Proc. Natl. Acad. Sci.*, 2022.

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Canola added to Renewable Fuel Standard program

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

In April, the United States, Environmental Protection Agency (EPA) proposed an approval for canola oil to participate in the Renewable Fuel Standard (RFS) program, clearing new pathways for alternative fuel options. The proposal would allow canola oil to be used as a feedstock for renewable diesel, jet fuel and other fuels. The approval is part of an effort to “spur the development of homegrown biofuels to expand Americans’ options for affordable fuel in the short-term and to build real energy independence in the long-term by reducing our reliance on fossil fuels,” according to a statement by the Biden administration.

The White House is interested in expanding the use of biofuels and says renewable diesel made from canola would have 63% to 69% lower greenhouse gas emissions than conventional diesel. A lifecycle greenhouse gas (GHG) emissions reduction threshold of 50% is required by the US Energy Independence and Security Act of 2007 (EISA).

“We’re excited that EPA determined that canola could be used as an advanced fuel under that RFS standard or program,” US Canola Association Board President Andrew Moore, who farms near Resaca, Georgia, said in an interview with *Agri-Pulse* magazine (<https://tinyurl.com/2p8m5tys>). “We know that it has potential to open up some different pathways for different producers to be able to utilize different markets.”

According to *Biomass Magazine*, canola oil biodiesel now qualifies as both an advanced biofuel and as biomass based diesel (<https://tinyurl.com/syzp8msp>). Further the final rule may allow the opportunity for producers of canola oil biodiesel to generate either advanced or biomass-based diesel Renewable Identification Numbers (RINs) for such fuel that they produced dating back to July 1, 2010. The EPA states that the Delayed RIN

provision: “would apply only to those producers who use canola oil, grain sorghum, pulpwood or palm oil to produce renewable fuel, only for renewable fuel produced in 2010.”

Five months after releasing the final rule for the revised renewable fuel standard (RFS2), the EPA released a Notice of Data Availability, stating that the canola oil biodiesel pathway creates a 50 percent reduction in greenhouse gas emissions compared to the diesel fuel baseline. Using the same RFS2 life-cycle analysis modeling for other biofuels already approved, the EPA also compared canola oil conversion efficiencies to biodiesel produced from soybean oil. The final analysis shows that one pound of canola produces 0.40 pounds of oil compared to soybean’s 0.18 pounds of oil.

The EPA notes the current capacity of canola-based biodiesel production spread between Archer Daniels Midland Co., Imperium Renewables Inc., Western Dubuque Biodiesel LLC, Inland Empire Oilseeds and Sun Power Biodiesel, is 226 million gallons a year.

Canola is predominantly planted in northern US states and Canada. According to the EPA, US canola acreage grew from 1.43 million acres in 2010 to 1.80 million acres in 2020. The US Department of Agriculture’s most recent Prospective Plantings report indicates that 2.2 million acres of canola will be planted in 2022 (<https://tinyurl.com/26cdf9nw>).

Agri-Pulse magazine reported that J. Alan Weber, an economist at MARC-IV who also works with Clean Fuels Alliance America, does not foresee a substantial increase in canola acreage in response to the ruling in the near term. He said it will likely take at least a year from enactment to see any growth, since EPA still needs time to review comments and many biofuel producers have already contracted with feedstock suppliers.

Likewise, Dale Thorenson, assistant director for the US Canola Association, told *Biomass* online he believes no producers will opt to create delayed RINs for canola biodiesel. “Producers large and small have had to stop production due to lack of demand since biodiesel buyers are unwilling to take the risk that canola might not qualify,” Thorenson said in the article. “There may be increased use of canola,” he also added, “because some biodiesel plants that are regionally located far from soybean supplies will increase production from canola oil to meet the RFS2 mandates.”

With vegetable oil prices skyrocketing worldwide, producers should be relieved to have an alternative feedstock. The EPA’s approval now give producers flexibility to adjust to market conditions by sourcing cost-effective feedstocks. For example, canola oil is currently more expensive than soybean oil. For the year beginning Oct. 1, 2021, the average price of canola oil is 85 cents a pound in the Midwest, while soybean oil is valued at 68 cents a pound, according to the US Department of Agriculture.

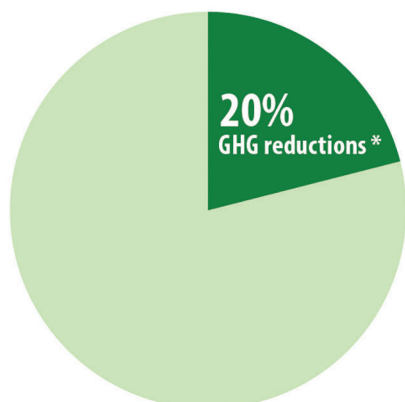
Some experts predict canola will maintain its primary role as a food oil and will not experience a significant increase in demand from renewable fuel producers in the US.

Barring any changes coming from a 30-day comment period, canola is the first of several fuel pathways not included in the original RFS2 decision. The EPA expressed a commitment to approve more new petitions for renewable fuels that can provide greenhouse gas benefits as well as reduce reliance on petroleum fuels. US producers are awaiting rulings on palm oil and pulpwood, as well as a handful of cover crops. While the EPA would not speculate on the analysis of new pathways, palm oil modeling is expected to come out mid-November.

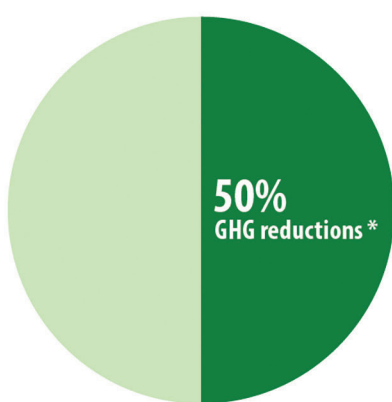
Lifecycle Greenhouse Gas (GHG) Emissions

GHG emissions must take into account direct and significant indirect emissions, including land use change.

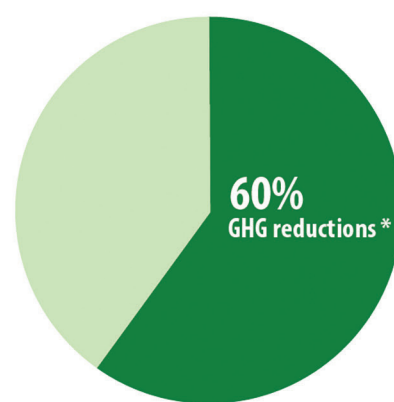
Renewable Fuels



Advanced & Biodiesel Fuels



Cellulosic Fuels



* compared to a 2005 petroleum baseline

For a fuel to qualify as a renewable fuel under the RFS program, EPA must determine that the fuel qualifies under the statute and regulations. Among other requirements, fuels must achieve a reduction in greenhouse gas (GHG) emissions as compared to a 2005 petroleum baseline. Source: epa.gov

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High Oleic Oils: Development, properties, and uses

Based on the book *High Oleic Oils: Development, Properties, and Uses*

August 1—5, 2022 | 10:00 a.m.—1:00 p.m. CDT (Chicago, USA; UTC-05)

Organizer and facilitator: Frank Flider, editor of *High Oleic Oils*

Fundamentals of Spectroscopy in the Analysis of Fats and Oils

October 19, 2022 | 9:00 a.m.—Noon CDT (Chicago, USA; UTC-05)

Instructor: Jonathon D. Speed, PhD, CChem, Product and Applications Manager,
Keit Spectrometers

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Meet Tony O'Lenick

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

PROFESSIONAL

What's a typical day like for you?

Our business develops solutions for customers looking to solve specific formulation problems. We are concentrating on natural products and products derived from them, so topics vary widely. There's never a boring day!

My favorite part of my job is...

Dealing with people who have an interest in technology. We tend to think of mentors and educators as the "old people" and students as the "young generation." This is a very narrow view. We can all be mentors and be mentored.

Flash back to when you were 10 years old. What did you want to be when you grew up?

It was about that age when I developed my first interest in chemistry. I was forever mixing things together and enjoying seeing the result. Shortly thereafter, my parents bought me my first chemistry set; I have had one ever since.

Is there an achievement or contribution you are most proud of? Why?

Over my career I have written eight books and I am listed as an inventor on more than 300 patents. Nonetheless, I am most proud of teaching and mentoring associates. The chance to give knowledge back to others is tremendously satisfying. No knowledge is ever wasted; it may take time until it can be used, but one simply needs to be patient. I am also very proud to have had the opportunity to develop a family business in which I work with my wife and three sons daily.

What event, person, or life experience has had the most influence on the direction of your life?

I was fortunate to meet my wife very early in my career. She was the one who suggested we start our own company and who believed in the possibility of its success more than I did.



Tony O'Lenick

Fast facts

Name	Tony O'Lenick
Joined AOCS	1996
Education	MSc in chemistry from Rutgers University (Newark, New Jersey, USA)
Job title	President
Employer	SurfaTech Corp. (Lawrenceville, Georgia, USA)
Current AOCS involvement	Session chair and presenter for multiple surfactants and detergents sessions. Member-at-roles large, Governing Board (2015–2021). Winner, Samuel Rosen Memorial Award (1996).

PERSONAL

How do you relax after a hard day of work?

By reading and enjoying time with my wife, three sons, three daughters-in-law, and eight grandchildren.

What are some small things that make your day better?

Family contacts, meeting with associates, volunteering for associations like AOCS, solving technical problems, and inventing new products.

What are you looking forward to in the coming months or years?

I have decided that when you enjoy what you do you never need to retire. Work becomes pleasurable.

Is there anything else you'd like to say to your peers?

We live in interesting times. We can either complain or do something about it. The best of technology has yet to be discovered.

PATENTS

Oil-based compositions for enhancing oral health and general wellness in humans

Hall, Gary, US11109607, September 7, 2021

An oil-based composition comprises a glyceride of medium-chain fatty acids, at least one essential oil selected from the group consisting of cinnamon oil, oregano oil, avocado oil, coconut oil and apricot oil, and optionally cinnamon bark. The medium-chain fatty acid comprises about 6 to 12 carbon atoms. The oil-based composition may be used for oral hygiene applications, weight control applications, skin care applications, or treatment of *Staphylococcus aureus* infection.

Systems and methods for electrochemical triglycerides assays

Hughes, Gary, Polymer Technology Systems Inc, US11112376, September 7, 2021

A system for the electrochemical detection of triglyceride levels includes a test strip including an electrode and a counter electrode, the electrode and counter electrode located proximate to a sample reception area; and a coating on one of the electrode and counter electrode, the coating including a reagent coating for triglycerides.

Use of rice bran oil distillate extract for prevention and mitigation of the effects of radiation

Compadre, Cesar, M., *et al.*, Tocol Pharmaceuticals LLC, US11116746, September 14, 2021

Provided herein is a tocol rich fraction of rice bran oil deodorized distillate that is shown to be both radioprotective and able to protect against oxidative damage. This fraction may prove an inexpensive and readily available extract that can be used to prepare pharmaceutical compositions for use in protecting against radiation exposure and/or other forms of oxidative stress.

Protein rich food ingredient from biomass and methods of production

Rutt, George C., *et al.*, Synthetic Genomics Inc and Smallfood Inc, US11122817, September 21, 2021

The present invention provides a protein material and food ingredient from a sustainable and stable source. The sustainable and stable source of the food or food ingredient is cellular biomass, for example an algal or microbial biomass. The invention discloses that the cellular biomass can be subjected to a series of steps to

derive the protein material and food or food ingredient, which has high nutritional content and has pleasing organoleptic properties.

Synthesized lubricants for water-based drilling fluid systems

Amanullah, M.D., *et al.*, Saudi Arabian Oil Co, US11124687, September 21, 2021

The present application discloses water-based drilling fluid systems and methods of making water-based drilling fluids systems. According to one embodiment, a drilling fluid system may include a drilling fluid and a lubricant. The lubricant may be synthesized from waste vegetable oil.

Catalyst for high throughput enzymatic catalysis

Iftime, G., *et al.*, Palo Alto Res Ct Inc, US11124790, September 21, 2021

A catalyst having a porous support having at least one of thermally or electrically conductive particles bonded by a polymer, and enzymes embedded into pores of the porous support. A process of manufacturing an enzyme-embedded porous support includes forming solution of monomers, enzymes, a solvent, and at least one of electrically and thermally conductive particles, polymerizing the monomers by adding initiators to the solution, and evaporating the solvent to produce an enzyme-embedded porous support. A process of manufacturing an enzyme embedded porous support, includes mixing enzymes, at least one of electrically conductive or thermally conductive particles, and a polymer in a solvent, and evaporating the solvent.

System and method for producing concentrated cream

Glenn III, T.A., *et al.*, Land O'Lakes Inc, US11129393 September 28, 2021

Concentrated creams are produced from starting cream compositions characterized as homogenous, oil-in-water emulsions containing fat globules, phospholipid membrane components and non-fat solids, and which have an initial fat content between about 35 to about 55 percent by weight. To produce the concentrated creams, moisture is removed from the starting cream compositions through evaporative processing, and as a result, the concentrated cream remains in a homogenous state, retains the fat globules, phospholipid membrane components and non-fat solids, and includes a concentrated fat content of at least about 70 percent by weight. In addition, the concentrated cream may be in an oil-in-water or a bi-continuous emulsion. Evaporative processing may be through a wiped film evaporator or a scraped surface heat exchanger.

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.



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Promoting your paper on Twitter

Katya Mameishvili

With approximately 2.5 million new scientific articles published every year, researchers need to find the right ways to ensure their work gets noticed. Among other platforms for sharing research, such as ResearchGate or Mendeley, scientists are particularly active and collaborative on Twitter: asking for advice, discussing relevant research topics, forming new scientific collaborations, and finding new mentors and jobs.

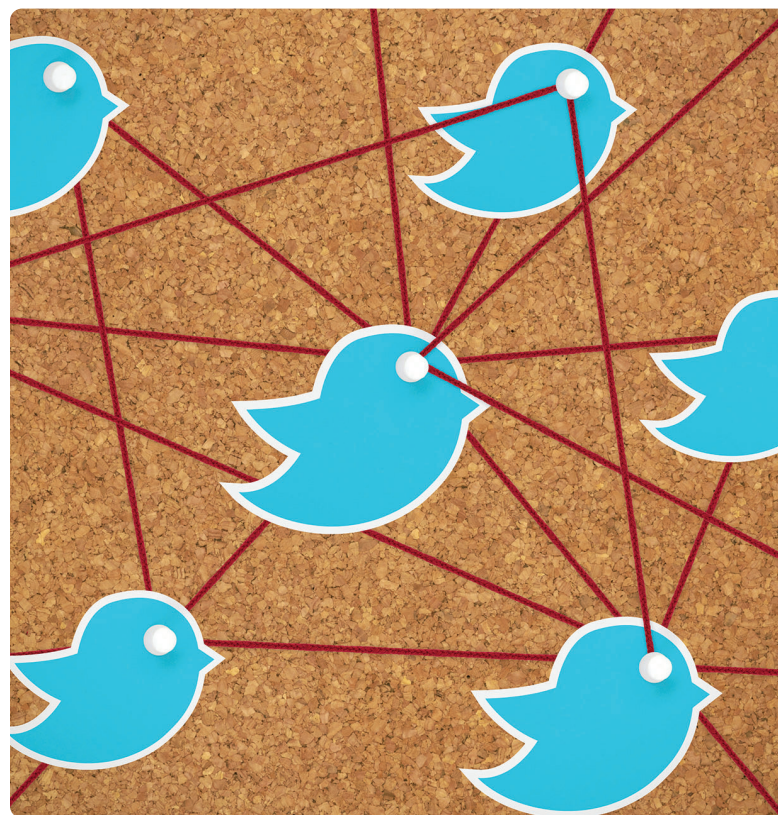
Tweeting about your research can help you develop your professional circle, especially if you are in the early stages of your scientific career. It can also assist in launching new research projects and getting support and advice from the scientific community. Here we want to highlight how tweeting your next paper or preprint can benefit your publication and your research in general.

EXPAND YOUR PAPER'S REACH

Many researchers do not actively engage in spreading the results after the publication of their paper. Circulating newly published papers on Twitter not only allows for more exposure but can lead to an increased number of citations of your paper over time.

The Journal of Medical Internet Research (JMIR) conducted a three-year study of the relative success of JMIR articles in both Twitter and academic worlds (<https://www.jmir.org/2011/4/e123/>). They found that highly tweeted articles were 11 times more likely to be highly cited than less tweeted articles. The study also showed that tweets could predict highly cited articles within the first three days of publication. The results of this study suggest a correlation between Twitter activity and a subsequent number of citations. However, the study does not prove that tweeting itself increases the citation number.

To investigate the latter question, another study in cardiovascular surgery publications was conducted ([https://pubmed.](https://pubmed.ncbi.nlm.nih.gov/32504611/)



[ncbi.nlm.nih.gov/32504611/](https://pubmed.ncbi.nlm.nih.gov/32504611/)). The authors randomly chose half of 112 papers to be shared on Twitter, while another half was not tweeted. Over one year, tweeted papers accumulated four times more citations, compared to non-tweeted papers. These results suggest that tweeting your article results in significantly more citations over time.

Twitter mentions have become an important alternative metric, or altmetric, a way of tracking the non-academic attention a paper receives. Furthermore, there have been attempts to establish “Twitter impact factor” to measure a journal’s academic influence in the realm of social media (<https://tinyurl.com/d552wa2n>). All the studies and initiatives, discussed above, indicate that as a scientist you cannot ignore the value of sharing your publications and research on Twitter.

GAIN RECOGNITION FOR YOUR WORK

When looking up articles on PubMed or Google Scholar, many scientists pay attention only to the last author of the article (usually group leader or professor), and they often do not

know the PhD students or postdocs who performed the work. If you tweet about your freshly published paper, you make your network of highly relevant academics aware of your work. Those academics will now associate this publication with your name. In this way, Twitter can help you build your reputation in your research field. Also, it will be gratifying to see the attention your paper is getting in real-time.

If your supervisor is active on Twitter, you can ask them to tweet your paper, highlighting your input in the project. This will further benefit your reputation among peers and more established scientists. Also, it's a good idea to ask your institute or university twitter account to tweet your article; this will allow your paper to reach their broad audience.

REACH A NON-SCIENTIFIC AUDIENCE

If you are passionate about science communication, consider using Twitter to extend your reach beyond the scientific audience. A recent study highlighted the fact that tweeting academics had the potential to disseminate scientific information to non-scientific audiences (<https://doi.org/10.1139/facets-2018-0002>). The results showed that scientists who have fewer than 1,000 followers are primarily followed by other scientists; however, beyond this threshold, the tweets of academics can reach a more varied audience, composed primarily of non-scientists.

Twitter, therefore, offers an opportunity for scientists to reach a wide popular audience. However, science outreach to the public on Twitter will require sustained online engagement and a certain threshold number of followers.

TELL A STORY BY COMPOSING A THREAD OF TWEETS

Most scientists agree on the importance of telling a persuasive story about your research. On Twitter, you can tell your scientific narrative in the format of a series of tweets—a thread.

Think about how you would present your published work at a conference. You already have the building blocks of your story such as figures, section titles, and key messages from your manuscript. You can choose some of these blocks to help you tell your story on Twitter, just like you would prepare your presentation for a conference. Take time to compose a thread of tweets that convey your key findings—you want to make sure you are telling a persuasive and cohesive story.

The first tweet of the thread is crucial since all the following tweets will be posted as replies to this initial tweet. This first tweet should grab the reader's attention and persuade them to read the whole thread and check out your paper.

ADD A VISUAL FOCUS

Do you know that tweets with photos and videos are retweeted more often than text-only tweets? Twitter analysis of over 2 million tweets showed that tweets with photos and videos gain on average 35% or 28% boost in retweets, respectively. Therefore, when composing your thread, try to accompany each tweet with an image or video.

For your first tweet in the thread, try to choose the best visual representation of your results. All these beautiful visualizations will not only illustrate your results but also engage the reader. You can also use a photo of your model organism, your lab, your experimental setup, screen-grab of the pdf, or a gif animation—any visualization to support a key message of your tweet. There is no limitation for your creativity here!

USE TAGS AND HASHTAGS

Consider carefully whom to tag, especially in your initial tweet. It is a good practice to tag your co-authors. You can also tag your supervisor, funding agencies, your institution, and even your lab twitter (if you have one).

Throwing in an amplifier—one of your followers with many followers themselves—can help you reach a much wider audience in case they re-tweet you. You can find out your potential amplifier using Twitter Analytics, which is a great tool to measure and boost your impact on Twitter (<https://analytics.twitter.com>). The best strategy is to choose an amplifier who is genuinely interested in your research field and may, therefore, find your paper useful and worth re-tweeting.

Using hashtags (#) will make your tweets visible to a wider audience, for example, #SciComm or #PhDchat. Check which hashtags scientists you are following are using and add them in. Find out if there is a specific hashtag popular within your research field as it will help you reach more scientists specializing in your field.

DON'T FORGET A LINK TO YOUR PAPER

With the length of tweets being limited to 280 characters, make sure to allocate some space for the link to your publication or preprint. Using URL shorteners like bitly.com or tinyurl.com will help you save space when adding links.

To send your followers directly to your publication, you can also use the DOI—a unique alphanumeric code that works as a persistent link for an article.

REPEAT THE STORY

With approximately 2.5 million new scientific articles published every year, it is easy to miss even relevant papers in your research field. So, once you have got your story together, you need to repeat it to make sure your paper achieves maximal exposure and engagement. Ask your supervisor, lab colleagues, and university twitter account to share your tweet thread and add a few words from their perspective.

You can also coordinate your tweeting strategy with your co-authors. Consider if it is more efficient for you all to tweet and re-tweet your paper on the same day or spread tweets over a week or month.

Now you should feel fully prepared to compose a thread of tweets about your next publication.

This article by science writer Katya Mameishvili was republished from two TipBox articles (<https://tipbox.abcam.com/twitter-for-academics-five-reasons-to-tweet-your-next-paper-or-preprint/>) published online September 21 and June 7, 2020.

EXTRACTS & DISTILLATES

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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

H&N EAT IOP PRO Fractionated palm oils: emerging roles in the food industry and possible cardiovascular effects

Yilmaz, B. and Ağagündüz, D., *Crit. Rev. Food Sci. Nutr.*, 62, 1990–1998, 2022. <https://doi.org/10.1080/10408398.2020.1869694>

The public health debate about fats and human health has been ongoing for a long time. Specifically, the fat types commonly used in the food industry and the techniques used in extracting them are remarkable in terms of human health. Among these, palm oil, which is mainly associated with cardiovascular disease (CVD), is a vegetable oil type that is widely used in the food industry. Moreover, the fractionation of palm oil has become quite common in the food industry when compared to other culinary oils and fats. Fractional crystallization, which has been recently regarded as an alternative to hydrogenization and interesterification methods, has become more popular in edible oil technology, even though it is an ancient method. The main fractions of palm oil are palm olein and palm stearin. Palm oil fractions, which have some pros and cons, are used in edible oils, such as margarine/shortening, as well as bread and cake-like pastry production. Since the fatty acid composition of palm oil, palm kernel oil, and their fractions is different, each type of oil needs to be evaluated separately with regards to their CVD effects and food preparation applications. However, the effects of the fractionation method and the fractional palm oil produced on health are controversial in the literature. In this review, the use of palm oil produced via the fractional crystallization method in the food industry and its potential CVD effects were evaluated.

EAT LOQ Maillard reaction products as functional components in oil-in-water emulsions: A review highlighting interfacial and antioxidant properties

Feng, J., *et al.*, *Trends Food Sci. Technol.*, 121, 129–141, 2022. <https://doi.org/10.1016/j.tifs.2022.02.008>

Lipid oxidation gives rise to the formation of off-flavors and is therefore a major concern for food quality. When present in food emulsions (e.g., milk, yogurts, salad dressings), labile polyunsaturated lipids usually oxidize faster than in bulk oil, which can be mitigated by antioxidants. However, the use of synthetic antioxidants is not desired from a “clean-label” point of view. Therefore, we focus on the potential of Maillard reaction products (MRPs), which are biobased molecules that are formed during heating, and of which some may possess excellent antioxidant and emulsifying properties.

The *in situ* antioxidant activity of MRPs in emulsion systems is reviewed; effects occurring in the continuous phase and at the interface of oil-in-water (O/W) emulsions are distinguished. A dedicated section of the review focuses on the MRPs that are intrinsically present in various foods.

MRPs may partition between the continuous phase and the oil-water interface in emulsions, which allows them to counteract lipid oxidation by various physicochemical mechanisms, including metal chelation and free radical scavenging. MRPs intrinsically present in foods are promising components to achieve food products with high oxidative stability, while complying with consumer points of view.

Original Articles

BIO PCP Production of high levels of 3S,3'S-astaxanthin in *Yarrowia lipolytica* via iterative metabolic engineering

Zhu, H., *et al.*, *J. Agric. Food Chem.*, 70, 8, 2673–2683, 2022. <https://doi.org/10.1021/acs.jafc.1c08072>

Astaxanthin is a highly value-added keto-carotenoid compound. The astaxanthin 3S,3'S-isomer is more desirable for food additives, cosmetics, and pharmaceuticals due to health concerns about chemically synthesized counterparts with a mixture of three isomers. Biosynthesis of 3S,3'S-astaxanthin suffers from limited content and productivity. We engineered *Yarrowia lipolytica* to produce high levels of 3S,3'S-astaxanthin. We first assessed various β -carotene ketolases (CrtW) and β -carotene hydroxylases (CrtZ) from two algae and a plant. HpCrtW and HpCrtZ from *Haematococcus pluvialis* exhibited the strongest activity in converting β -carotene into astaxanthin in *Y. lipolytica*. We then fine-tuned the HpCrtW and HpCrtZ transcriptional expression by increasing the rounds of gene integration into the genome and

applied a modular enzyme assembly of HpCrtW and HpCrtZ simultaneously. Next, we rescued leucine biosynthesis in the engineered *Y. lipolytica*, leading to a five-fold increase in biomass. The astaxanthin production achieved from these strategies was 3.3 g/L or 41.3 mg/g dry cell weight under fed-batch conditions, which is the highest level reported in microbial chassis to date. This study provides the potential for industrial production of 3S,3'S-astaxanthin, and this strategy empowers us to build a sustainable biorefinery platform for generating other value-added carotenoids in the future.

BIO Engineering the lipid and fatty acid metabolism in *Yarrowia lipolytica* for sustainable production of high oleic oils

Wang, K., *et al.*, *ACS Synth. Biol.*, 11, 4, 1542-1554, 2022.
<https://doi.org/10.1021/acssynbio.1c00613>

Oleic acid is widely applied in the chemical, material, nutritional, and pharmaceutical industries. However, the current production of oleic acid via high oleic plant oils is limited by the long growth cycle and climatic constraints. Moreover, the global demand for high oleic plant oils, especially the palm oil, has emerged as the driver of tropical deforestation causing tropical rainforest destruction, climate change, and biodiversity loss. In the present study, an alternative and sustainable strategy for high oleic

oil production was established by reprogramming the metabolism of the oleaginous yeast *Yarrowia lipolytica* using a two-layer “push-pull-block” strategy. Specifically, the fatty acid synthesis pathway was first engineered to increase oleic acid proportion by altering the fatty acid profiles. Then, the content of storage oils containing oleic acid was boosted by engineering the synthesis and degradation pathways of triacylglycerides. The strain resulting from this two-layer engineering strategy produced the highest titer of high oleic microbial oil reaching 56 g/L with 84% oleic acid in fed-batch fermentation, representing a remarkable improvement of a 110-fold oil titer and 2.24-fold oleic acid proportion compared with the starting strain. This alternative and sustainable method for high oleic oil production shows the potential of substitute planting.

BIO PCP IOP PRO A unique bacterial pelletized cultivation platform in *Rhodococcus opacus* PD630 enhanced lipid productivity and simplified harvest for lignin bioconversion

Xu, B., *et al.*, *ACS Sustain. Chem. Eng.*, 10, 3, 1083-1092, 2022.
<https://doi.org/10.1021/acssuschemeng.1c05239>

Pelletized liquid cultivation has been widely explored because of its advantages in biomanufacturing, such as easier biomass harvesting, higher product yield, and lower medium viscosity and

AOCS methods cover critical measures of quality for raw materials and products for edible oils and fats, surfactants, phospholipids, plant proteins, and related materials.

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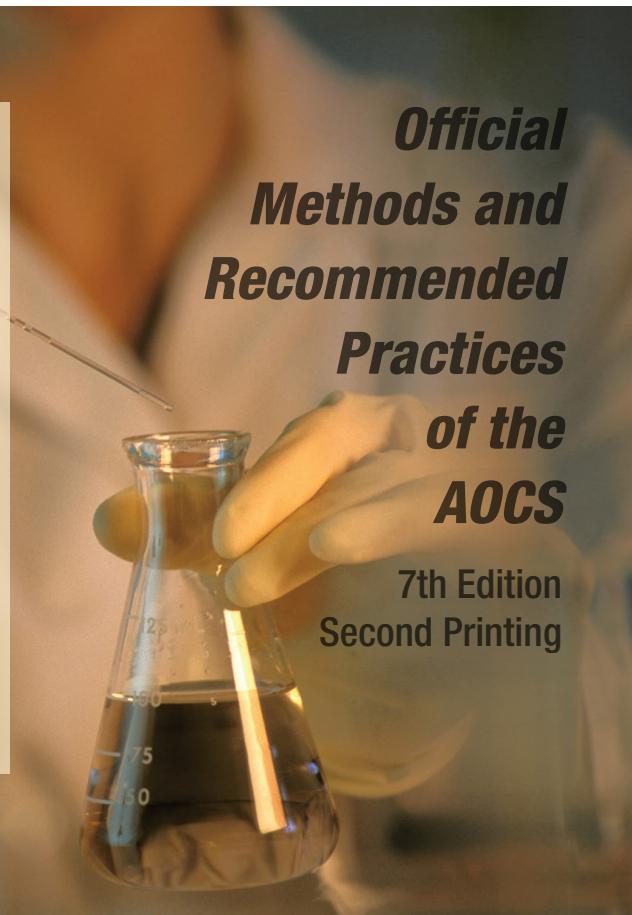
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energy consumption. In this study, we discovered that the nonfilamentous bacterium *Rhodococcus opacus* PD630 could form pellets during the fermentation of alkaline pretreatment liquor containing lignin as a carbon source. This discovery advanced our understanding of bacterium pelletization, as only filamentous fungi and filamentous bacteria were reported to form pellets without the addition of external agents such as flocculants or polymers in previous research. Several factors were investigated to understand how they affect the process of pelletization. Notably, the lipid content in the pellets was much higher than in the scattered bacteria at low nitrogen concentration (<0.5 g/L), under which condition (high carbon to nitrogen ratio) the industrial microbial production for lipids was carried out. Moreover, the highest pellet percentage ($\sim 60\%$ of the total biomass) was observed at 30 g/L soluble solid content, an agitation rate of 180 rpm, 1.4 g/L NH_4NO_3 , an initial optical density (OD_{600}) of 10, and a centrifugation speed of 6000 rpm. The study also opens new avenues to decrease harvesting and cultivation cost as well as energy consumption for microbial fermentation.

IOP PRO Sustainable pilot-scale production of a *salicornia* oil, its conversion to certified aviation fuel, and techno-economic analysis of the related biorefinery

Laveille, P., *et al.*, *Biofuels Bioprod. Biorefining*, 16, 127-42, 2022.
<https://doi.org/10.1002/bbb.2260>

The 2 ha pilot-plant Seawater Energy and Agriculture System (SEAS) in Abu Dhabi, United Arab Emirates (UAE), integrates aquaculture ponds, which produce fish and shrimp, with fields of *Salicornia* and mangrove used as a natural filter to clean the waste seawater from the ponds. The SEAS is a sustainable solution that addresses the food security issues of countries with large deserts or arid regions. At the same time, it produces economically viable fuels from biomass, using non-arable lands and non-drinkable water. After harvesting and pressing *Salicornia* seeds ($2 \text{ t ha}^{-1} \text{ year}^{-1}$), a custom-made process serves to pre-treat the vegetable oil ($0.7 \text{ t ha}^{-1} \text{ year}^{-1}$) containing 85 wt% C_{18} and 10 wt% C_{16} fatty acids as triglycerides. The first step of the UOP Ecofining® process produces an oil composed of linear C_{15} - C_{18} alkanes. Analytical data suggest the oil feed converts at 60 wt% by hydrodeoxygenation and at 40 wt% through decarboxylation/decarbonylation. The subsequent hydrocracking/isomerization step provided 3.4 wt% C_1 - C_4 , 34.8 wt% green naphtha, 47.5 wt% sustainable aviation fuel (SAF), and 14.2 wt% green diesel. After distillation, the SAF has been certified following ASTM D7566 before being blended with conventional jet fuel and used successfully on a commercial passenger flight in January 2019. The techno-economic study shows that the biorefinery part is economically sustainable when reaching a production scale of 900 bbd, required for a SEAS surface of 20 000 ha. At this scale, expected revenue and conversion costs per MT of feed are, respectively, \$589 and \$290. The resulting benefit, associated with a CAPEX of \$115M, would lead to a payback time of 6.9 years.

IOP PRO Single-step catalytic deoxygenation of palm feedstocks for the production of sustainable bio-jet fuel

Why, E. S. K., *et al.*, *Energy*, 239, Part B, 122017, 2022.
<https://doi.org/10.1016/j.energy.2021.122017>

The production of jet fuel from renewable source (i.e., biomass) has been improving since the past few years. In Malaysia, palm-based biomass is being widely studied for the production of transportation fuels due to its abundant supply. Hence, this study focused on the production of bio-jet fuel from different types of palm oil (e.g., palm-based waste cooking oil, palm olein, palm kernel oil) through deoxygenation process. Several types of deoxygenation catalysts (e.g., CaO, Zeolite, V_2O_5 , Pd/C, TiO_2) were selected to investigate the efficiency of jet fuel-based hydrocarbon production under condition of 400°C for 2 h with different catalyst loading (e.g., 0 wt%, 5 wt%, 6 wt%, 7 wt%, 8 wt%, 9 wt% and 10 wt%). The physico-chemical properties of yielded liquid fuel were tested by using GC-MS analyses, as well as density, kinematic viscosity, cloud point, pour point, smoke point, flash point and final boiling point. The deoxygenation of PKO over Pd/C at 8 wt% yielded the highest molar concentration of 96% liquid product (e.g., *n*-paraffins, isoparaffins, olefins, naphthenes, aromatic) and 73% of jet paraffins selectivity (C_8 - C_{16}) under 400°C for 2 h. In addition, the physicochemical properties of palm-based liquid fuel are complied with standard Jet A-1 fuel, in accordance to ASTM standards. The low temperature fluidity, combustion characteristics, and fuel volatility of this liquid product were comparable to Jet A-1 fuel.

BIO Pyrolysis kinetics and pyrolysate composition analysis of *Mesua ferrea* L: A non-edible oilseed towards the production of sustainable renewable fuel

Komandur, J., *et al.*, *Bioresour. Technol.*, 351, 2022.
<https://doi.org/10.1016/j.biortech.2022.126987>

The present study on one non-edible oilseed (*Mesua ferrea* L) employs the pyrolysis process to understand the pyrolysate composition and the thermal degradation behavior of biomass. The physicochemical characterization of whole seed was investigated using thermogravimetric analysis at different heating rates (5, 10, 20, and $40^\circ\text{C min}^{-1}$), bomb calorimeter, proximate/ultimate analysis. FTIR analysis confirmed the presence of the lignocellulosic compounds. Kinetic analysis of biomass was investigated using *iso*-conversional models such as Friedman, Kissinger-Akhaire-Sunose, Ozawa-Flynn-Wall, Starink, Distributed Activation Energy model, and Avrami model. Further, composition analysis of the pyrolytic vapor was analyzed using analytical fast pyrolysis coupled with gas chromatogram/mass spectrometer (Py-GC/MS) at 400, 500, 600°C . This study confirmed that alkenes were major pyrolysates,



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For full details about the program, visit aocs.org/refer2022.

followed by alkanes and esters. The current investigation suggested that *Mesua ferrea* L whole seed can be converted to valuable chemicals using pyrolysis.

EAT Quantifying cooperative flow of fat crystal dispersions

Klaudia W. Milc, *et al.*, *Soft Matter*, 18, 2782, 2022.

<https://doi.org/10.1039/d2sm00233g>

We quantify the cooperative flow behaviour of fat crystal dispersions (FCDs) upon varying crystallization conditions. The latter enabled altering the multiscale microstructure of the FCDs, from the nanometersized platelets, and the dispersed fractal aggregates, up to the strength of the mesoscopic weak-link network. To the goal of characterizing strongly-confined flow in these optically-opaque materials, we acquire high-resolution rheo-magnetic-resonance-imaging (rheo-MRI) velocimetry measurements using an in-house developed 500 mm gap Couette cell (CC). We introduce a numerical fitting method based on the fluidity model, which yields the cooperativity length, x , in the narrow-gap CC. FCDs with aggregates sizes smaller than the confinement size by an order of magnitude were found to exhibit cooperativity effects. The respective x values diverged at the yield stress, in agreement with the Kinetic Elasto-Plastic (KEP) theory. In contrast, the FCD with aggregates sizes in the order of the gap size did not exhibit any cooperativity effect: we attribute this result to the correspondingly decreased mobility of the aggregates. We foresee that our optimized rheo-MRI measurement and fitting analysis approach will propel further similar studies of flow of other multi-scale and optically-opaque materials.

EAT Effect of tempered procedures on the crystallization behavior of different positions of cocoa butter products

Wentao Liu, *et al.*, *Food Chemistry*, 370, 131002, 2022.

<https://doi.org/10.1016/j.foodchem.2021.131002>

The effects of tempered procedures (well and under-tempered) on the crystalline behaves of cocoa butter were elaborated through detecting crystalline structure and compositions of crystals located at different positions of cocoa butter products in this study. The under-tempered products couldn't form crystalline structures as uniform as the well-tempered ones, whose internal contained more low saturated triacylglycerol and structurally unstable crystals. The low saturated triacylglycerol further created the diverse microstructure and thermal properties between center and outer part of cocoa butter products. During storage, the concentration differences drive migration of low saturated triacylglycerol from center to outer part of the product. Although this reduces the differences in triacylglycerol composition, it results in the polymorphism conversion between β' -IV and β -VI form and the fat bloom formation. This work indicates that the monitor for crystalline properties of

different positions in cocoa butter products helps the chocolate industry to control formation of fat bloom.

EAT LOQ Valorization of fruit and vegetables agro-wastes for the sustainable production of carotenoid-based colorants with enhanced bioavailability

Cassani, L., *et al.*, *Food Res. Int.*, 152, 110924, 2022.

<https://doi.org/10.1016/j.foodres.2021.110924>

Carotenoids are pigments naturally occurring in fruits and vegetables, and responsible for their yellow to red colors. They also have several bioactive properties, making them interesting alternatives to the artificial colorants commonly used in the food industry. This review compiles an updated research progress about green production of carotenoid-based colorants focusing on the benefits associated with their sustainable extraction from agro-wastes, also considering the environmental aspects associated to the processes. Taking into account the hydrophobic nature of carotenoids and their susceptibility to degradation when exposed to technological and/or storage conditions (e.g., light, heat, and oxygen), protecting strategies based on nanotechnological approaches were presented as tools to avoid degradation and thus, retain the bioactive properties. Additionally, the effect of such nanotechnological strategies on carotenoids bioaccessibility and bioavailability was reviewed and discussed. Finally, the health-related properties of carotenoids that make them promising candidates to be used not only as functional food ingredients but also in therapeutic applications and in the nutraceutical and cosmeceutical industries were also considered.

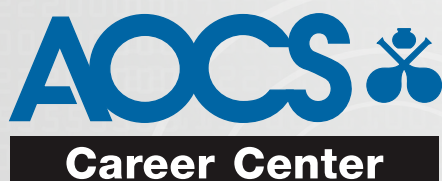
EAT LOQ Phenolic compounds from passion fruit rinds using ultrasound-assisted pressurized liquid extraction and nanofiltration

Tamires D., *et al.*, *J. Food Eng.*, 325, 110977, 2022.

<https://doi.org/10.1016/j.jfoodeng.2022.110977>

Ultrasound-Assisted Pressurized Liquid Extraction (UAPLE) and Nanofiltration (NF) were performed in 70% ethanol to recover and concentrate bioactive compounds from passion fruit rinds. Polyamide Thin-Film Composite membranes with nominal MWCO between 150 and 300 Da provided good retention of phenolic compounds (74–89%) and antioxidant capacity (84–96%) with a maximum mass concentration factor 1.4. The membrane surface showed particle deposition and fouling after filtration using AFM, SEM and FTIR, resulting in reductions of permeate mass fluxes of 50–57%. Isoorientin was the main phenolic compound found in the retentates. Integrated UAPLE and NF is a promising process to recover and concentrate phenolic compounds from passion fruit rinds.

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EAT LOQ Simultaneous extraction of sunflower oil and active compounds from olive leaves using pressurized propane

Jaski, J. M., *et al.*, *Curr. Res. Nutr. Food Sci.*, 5, 531-544, 2022.
<https://doi.org/10.1016/j.crfs.2022.03.002>

Sunflower is grown in different parts of the world and oil from the grain has many uses, including cosmetics and food. Olive leaves are rich in active compounds with potential for industrial use. The simultaneous extraction of raw materials is an economical and sustainable way of using the same extraction process to obtain products with high added value. The aim of this work was to promote the incorporation of bioactive compounds from olive leaves in sunflower oil by two extraction techniques: pressurized propane (PRO) and Soxhlet (SOX) and to evaluate the increase in oxidative stability and antioxidant activity of oils. The techniques used were useful in producing sunflower oil incorporating olive leaf extract (SFO + OLE); 4.3% 1-octacosanol and 5.8% 1-triacontanol were incorporated, and β -sitosterol increased by at least 90%. Also, SFO + OLE showed an increase in the induction time of 2.7 and 3.7 h compared to SFO for the PRO and SOX methods, respectively. The profile of fatty acids was maintained, with the majority in all samples being oleic and linoleic acids. Consequently, with this procedure is possible to produce SFO + OLE with better antioxidant activity and better nutritional characteristics using PRO and SOX. The scaled-up of the simultaneous extraction process via pressurized propane is economically viable according to the process simulation and economic evaluation.

EAT ANA Safety assessment of citrus and olive by-products using a sustainable methodology based on natural deep eutectic solvents

Socas-Rodríguez, B., *et al.*, *J. Chromatogr. A*, 1669, 462922, 2022.
<https://doi.org/10.1016/j.chroma.2022.462922>

In this work, the application of betaine-based hydrophilic natural deep eutectic solvents (NADESs) as green extraction solvents was proposed for the first time for the evaluation of twelve pesticides in citrus and olive by-products intended to be applied as potential sources of compounds with neuroprotective activity against Alzheimer Disease. Ultrasound-assisted extraction of selected pesticides was followed by separation and determination using gas chromatography coupled to single quadrupole mass spectrometry. Eight NADESs were tested using different hydrogen bond donors (i.e. citric and lactic acid, fructose, glucose, glycerol, propylene glycol, propionic and butanoic acid). Other factors affecting extraction efficiency were also evaluated using a step-by-step approach. Eight mL of a mixture composed of 60% beta-

ine:propylene glycol NADES at a molar ratio 1:4 and 40% of water, as well as 30 min of ultrasound-assisted extraction were selected as the most adequate conditions. The methodology was validated prior to its application in citrus and olive by-products. Recovery values were between 73 and 115% (RSD% < 20%), while limits of quantification of the method were in the range 8.5–128.8 $\mu\text{g/kg}$, which demonstrates the suitability of the procedure to determine the selected group of pesticides, usually applied in citrus and olive crops, at the legislated levels. The greenness of the procedure was also evaluated using AGREE calculator. Finally, the whole method was applied for the safety assessment of seven olive leaf samples and seven citrus by-products produced in Spain, finding the presence of several of the evaluated compounds at concentrations higher than the established limits for similar products.

BIO Advanced thermochemical conversion of algal biomass to liquid and gaseous biofuels: A comprehensive review of recent advances

Krishnan, R. Y., *Sustain. Energy Technol. Assess.*, 52, Part C, 2022.
<https://doi.org/10.1016/j.seta.2022.102211>

Algal biomass is considered to be one of the most promising feedstocks of importance for conversion into biofuels. With their benefits over other biomass feedstocks, such as sustainability, renewability and productivity, microalgae are one of the most promising biomass resources for use in thermochemical conversion processes. With this review, we hope to present the most recent information available on the commonly used thermochemical conversion procedures, which are hydrothermal liquefaction, pyrolysis, and gasification processes. The study evaluated both the quality and yield of liquid products (bio-oil) as well as gaseous products (syngas) derived by thermochemical conversion processes, to truly comprehend the effectiveness and feasibility of each method. It was found that the yield of bio-oil obtained through hydrothermal liquefaction was lower than the yield achieved through pyrolysis. However, the energy density, fuel properties and storage stability of hydrothermal liquefaction bio-oil are superior to those of pyrolysis bio-oil. This study also demonstrated that the gasification process has been the most energy-saving approach for the transformation of microalgae to syngas. Microalgae supercritical water gasification might be a good way to turn microalgae into high-heating-value gas without having to dry it first. Finally, the prospects and obstacles of converting microalgal biomass to biofuels were discussed. Overall, the purpose of this work is to present a comprehensive assessment of the most recent developments in microalgal biomass thermochemical conversion for the production of liquid and gaseous biofuels.

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