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The continued struggle over biofuel feedstocks

Rebecca Guenard

- Biofuels are becoming a mainstay around the world.
- Analysts believe competition for vegetable oils between food and fuel manufacturers will only increase since feedstock supplies like used cooking oil and tallow are fixed.
- Are non-edible oilseed cover crops likely to provide the next major feedstock?

In 1912, the inventor of the diesel engine, Rudolf Diesel predicted that someday our dependence on petroleum fuels would abate as their supply diminished, creating a market for new fuels sourced from animals and vegetables. That time has arrived.

Emissions from the internal combustion engine contribute to the concentration of carbon dioxide in the atmosphere. Scientists have proven that as the amount of these gases go up they cause a greenhouse effect over the planet, raising its temperature and leading to climate change. To reverse this effect, governments around the world have agreed to reduce their carbon emissions with an eventual net-zero goal (https://unfccc.int/).

The transportation sector, in particular, has been the focus of efforts to lower emissions. More auto manufacturers are adjusting their product line to include electric vehicles, but that will not eliminate the need for cleaner burning fuels. Farm equipment and other heavy machinery are difficult to power with batteries. The same is true for airplanes, which produce a significant amount of carbon. Of the total greenhouse gas emissions produced by the United States, for example, about 3 to 4% comes from aviation (https://tinyurl.com/2p875et6).

Reducing emissions may be a global concern, but the United States confronts unique challenges compared to the rest of the world. "In Europe, they just do not drive as much," says Bryan Yeh, president and CEO of American Biodiesel Community Fuels based in Walnut Creek, California, USA. Thus, US regulators are pushing harder on fuel refiners to incorporate lower emissions biofuels.

In December 2021, the US Environmental Protection Agency (EPA) proposed a 20% volume increase over 2020 values for its Renewable Fuel Standard program. In the months since, during the allotted comment period before the proposal takes effect, some food manufacturers testified in congressional hearings that the increase would induce market turmoil.

The outcry from food producers once again puts a spotlight on the Achilles' heel of biofuels: the need for an exclusive, reliable feedstock. How far have producers come in their efforts to find alternatives and are they truly more environmentally friendly?

IMPORTANT DISTINCTIONS

The term "biofuel" covers a wide range of products, including fuel ethanol, biodiesel, renewable diesel, renewable heating oil, and sustainable aviation fuel (SFA).

Compared to their petroleum-based counterparts, all these fuels emit less carbon dioxide when used to produce energy, but they are chemically distinct.

Biodiesel is made through a transesterification reaction which produces glycerin and fatty acid methyl esters. Triglycerides from soybean oil, palm oil, or beef tallow form the methyl ester biodiesel when reacted with methanol in the presence of a catalyst, such as sodium methoxide.

The resulting fuel is an oxygen-containing compound with properties that do not exactly match those of petroleum diesel (https://www.biodiesel.org/). In addition, some feedstocks can form waxy coatings that plug fuel filters in cold weather. Using the right feedstocks help eliminate these problems. In some cases, triglycerides are typically preprocessed to remove any free fatty acids.

Biodiesel is currently produced to specifications set by ASTM International, a standards organization. As a result, says Yeh, "past concerns about its use with new diesel engines are no longer valid." However, due to its oxygen content, biodiesel has higher NO_x emissions (Table 1) than other biofuels (https://doi.org/10.1007/978-1-4419-7145-6_15).

Renewable diesel and SFA, on the other hand, does not contain oxygen. They are hydrocarbon products formed when triglyceride molecules (from feedstocks similar to those mentioned above) react with hydrogen over a metal catalyst.
In 2007, the Finish company Neste was the first to produce renewable diesel (also known as Hydrotreated Vegetable Oil or HVO), and it is now the world's largest producer. The company currently has production sites in Finland, Singapore, and The Netherlands (https://www.neste.us/). They distribute renewable diesel to various locations on the West Coast of North America, and the company says it plans to expand its headquarters in Houston, Texas, USA, to better accommodate these markets.

TABLE 1. A list comparing the percentage emissions reduction of biodiesel. B20 indicates a fuel with an 80/20 ratio of petroleum to biodiesel and B100 indicates pure biodiesel. Note, biodiesel causes a NOx increase.

Source: DOE/GO-102001-1449, 2005.

Emission	B20 (% reduction)	B100 (% reduction)
carbon monoxide	12.6	43.2
hydrocarbons	11.0	56.3
particulates	18.0	55.4
air toxics	12-20	60-90
mutagenicity	20	80-90
nitrogen oxides	+1.2	+5.8

TOO MUCH, TOO SOON?

Neste did not remain the sole provider of renewable diesel for long. In the United States, companies that built refineries to process crude petroleum decades ago during the oil boom have recently repurposed their plants to produce the fuel. According to the production capacity reported by the companies that operate these plants, US renewable diesel production will increase by an order of magnitude in just a few years, from 0.5 billion to 5 billion gallons (https://www.npr.org/transcripts/1043413986).

Although former petroleum refineries are being converted for biofuel production world-wide, economics is driving US companies to make the switch, especially on the West Coast. "California is currently the only state that has The Low Carbon Fuel Standard program that incentives the selling of these products," says Yeh.

For nearly 20 years, California governors have legislated for the use of cleaner fuels. Most recently, the regulatory goal is to eliminate petroleum diesel emissions by 2030. According to Yeh, that will require 4 billion gallons of diesel equivalent biofuels yearly, for the state of California alone.

With increases in production mandated by the state of California and the US government, food manufacturers say they cannot buy soy and vegetable oils because supplies have gone to transportation. They testified to the US Congress that soybean oil prices more than quadrupled in the last quarter of 2021 due to increased demand by biofuel refineries (https://tinyurl.com/yckzfs8w).

Using 2020 data available from the US Energy Information Administration, Yeh calculated that soybean oil represents over 60% of biodiesel feedstock. And NPR reported that before the recent shift to biodiesel feedstock, a third of US-produced soybean oil was already dedicated to the product. Jeremy Martin, a member of the Union of Concerned Scientists, told NPR he is concerned land where higher carbon capture crops are currently grown will be turned over to soybeans to meet the escalating oil demands.

Yeh says, that is not likely for refineries selling biofuels to California, since they would be leaving money on the table. The state offers credits based on a biofuel's feedstock since greenhouse gas emissions can worsen or improve depending on the source.

FINDING LOW CARBON INTENSITY FEEDSTOCKS

Theoretical calculations for indirect land-use changes, or ILUC, first appeared in a paper published in 2008, by Princeton University researchers (https://doi.org/10.1126/science.1151861). Since then, ILUC has been extensively debated. Its intention is to measure the net change in greenhouse gas emissions when natural land, like rainforests and grasslands, which sequester carbon, are cleared and converted into croplands for biofuels. Despite its initial controversy, ILUC impact is now incorporated into renewable fuel standards in the United States (particularly in California), the United Kingdom, and the European Union.

"In the state of California, biofuel producers earn credits proportional to the carbon intensity of the feedstock used," says Yeh. "The carbon intensity of soybean oil is almost half of petroleum diesel, but used cooking oil is a quarter." When the credits for carbon intensity are applied, California producers receive $0.90 more per gallon for used cooking oil feedstock (Table 2). Therefore, there should be less incentive to use soybean oil. Incidentally, the United States Department of Agriculture (USDA) agrees with Yeh, projecting that the demand for soybean oil will remain steady in 2022 (https://tinyurl.com/bdekz5hz).

Market analysts differ with this opinion based on the fact that there is a limited amount of low-carbon feedstocks. Yeh acknowledges that West Coast ports have the benefit of easier access to shipments of used cooking oil from Asian markets. In general, lower carbon feedstocks are less accessible in landlocked areas where soybean is already being grown.

Analysts also point to the recent partnership between refineries and crushers as an indicator that soybean oil will continue to be a major feedstock. In December of 2021, ADM announced a joint venture with Marathon Petroleum Corp. that will own and operate a soybean processing plant to be built in North Dakota. The plant will exclusively supply oil to the refinery for renewable diesel fuel production (https://tinyurl.com/mr4253ay). Cargill announced a similar partnership with Paseo Biofuels earlier in the year (https://tinyurl.com/yck9c8s5).

If analysts and bakers are correct about a potential unfulfilled demand for soybean oil, biofuel refineries may have to secure other feedstocks. The market is providing a prime opportunity for a new source of triglycerides.

A NEW CROP OF FEEDSTOCKS

For over a decade the USDA has supported research projects across the country aimed at identifying high-yield oilseed crops that could be used to make biofuels. According to news reports, the investment is nearly ready to pay off.

"We know so much more about cover crops than we did five or six years ago," says Sheeja George, research proj-

TABLE 2. A comparison of the Low Carbon Fuel Standard (LCFS) credits biofuel producers receive in the state of California for using low carbon intensity feedstocks. Source: produced by Brian Yeh via https://ww2.arb.ca.gov/homepage.

	Petroleum Diesel	Biodiesel Soy	Biodiesel UCO	Biodiesel Tallow	SAF/Renewable Diesel Tallow
Carbon Intensity (gCO_2emision/MJ)	102	57.16	21.27	32.45	19.51
LCFS Credit ($/gal)	—	$0.90	$1.80	$1.52	$1.84

ect manager for the Southeast Partnership for Advanced Renewables from Carinata (SPARC) at the University of Florida in Quincy, Florida, USA. Thanks to a $15 million dollar grant from the USDA's National Institute of Food and Agriculture, the public-private partnership has researched a traditionally breed mustard seed variety, called *Brassica carinata*, as a non-edible oilseed crop for the production of biofuels.

"Carinata is about 40% oil, which is on par with soybean," says George. "And, depending on the variety, the meal is 35–40 % protein that then is available for animal feed markets."

Since industrial oilseed crops like pennycress, camelina, and carinata are non-edible, their use in the production of biofuels will not affect food manufacturers' bottom line. In addition, these crops are planted in the off-season when fields are typically idle which means their ILUC is neutral. According to George, carinata is in the process of undergoing US EPA certification to confirm this claim (among others) in preparation for making it eligible for sale in California.

Last May, an EPA representative told the news agency Reuters that camelina has already received approval (https://tinyurl.com/2s3r4ufz). Canadian seed developers report that popularity of the crop is growing. One producer says camelina oil tripled the company's sales in 2020.

At the same time, carinata was catching on in South America. In 2020, an Australian agrichemical company sold carinata (brand named Nuseed) to farmers in Argentina for commercial use. In the year since, all the oil produced from Nuseed has been sold to Saipol, a biodiesel producer in Grand-Couronne, France.

And Bayer AG and Bunge have invested millions in funding to develop a gene-edited variety of covercress customized for maximum oil and meal production, along with cold weather hardiness. The start-up the companies are supporting, CoverCress, based in St. Louis, Missouri, USA, has ambitions to plant 3 million acres of the new oilseed by 2030.

When asked what stands in the way of cover crops edging into the biofuel feedstock market, George says: production. Right now, there are not enough farmers planting these oilseed crops. She says there are a few reasons why.

The first is the US government's policy on agricultural insurance. According to George, a farmer can only claim insurance on a single crop per year. As the policy stands, farmers would have to assume the risk of planting a cover crop should it fail.

The next, possibly greater hurdle is tradition. "In the Southeast, particularly, farmers do not want to risk anything affecting their traditional crops which are cotton and peanuts," says George. A delayed harvest from a winter cover crop could negatively impact the start of planting preparations for their primary crops. "It will take early adopters to spread, by word of mouth, that they increased their soil health and their yearly revenue by planting cash-cover crops, like carinata," she says.

Finally, the cover crop means more work for the farmers. In the past, says George, after a fall harvest, farmers would spray down weeds and then take a break for a few months before preparing their summer crop. She says more farmers are shifting to the year-round farming necessary to maintain a cover crop, but the culture change will be slow until there is proof of a decent financial benefit for the extra effort.

Until carinata production increases, crushers may not be convinced to accommodate the crop in their facility to produce the oil needed for biofuels. Between processing an edible and non-edible oil the equipment must be thoroughly cleaned. High enough production could prompt processors to build new crush facilities and eventually establish a local supply chain.

New feedstocks cannot come too soon. In the US, emissions are back on the rise. Pandemic lockdowns in 2020 resulted in a 10% drop, but in 2021 they rebounded 6.2%. They are now just 17.4% below 2005 levels, well short of the 50% decrease the country hopes to achieve before 2030 (https://tinyurl.com/38ywxxmj).

Yeh says, although some US automakers are rethinking their engine designs, most of the car manufactures in Europe and China are making a greater commitment to electrification. Demand might not grow as fast in these regions. In the next five years current feedstock challenges are likely to peak, particularly in the Americas.

Rebecca Guenard is the associate editor of Inform *at AOCS. She can be contacted at rebecca.guenard@aocs.org.*

Two ways to hit the sweet spot with oats: how to use the versatility of enzymes to create oat beverages consumers want

James Chapa

- **Enzymes can be used to adjust many parameters of oat beverages including: taste, mouthfeel, and production efficiency.**
- **This versatility is shown through the comparison of two different concepts for optimizing sweetness—one designed for minimum enzyme use, the other for process efficiency and speed.**

All over the world consumers are embracing plant-based foods and beverages. This is leading to impressive growth in many new beverage categories —not least oat-based beverages. According to recent research, oat milk is the fastest growing segment in plant-based milk. Consumers appreciate that it is low in fat and sugar, and rich in protein. What's more, they are willing to pay extra for these claims. Many producers are now discovering how enzymatic treatment of oats enables them to create beverages that meet consumer needs— in a way that suits their production. The following case illustrates this using the example of sweetness.

Before we get into details, let's start with a look at the oats themselves. Varying based on the source and botanical variety, typical oats contain about 60% starch, 13% protein, 7% lipid, and 5% beta glucans (soluble fibers that result in high viscosity) (Rasane, et al, 2015). When oats are heated in water past a critical temperature, the gelatinization process occurs, and the starch granules rupture, leaching into solution amylose and amylopectin molecules– long polymers of glucose that differ in their molecular weight and degree of branching. Gelatinization makes starch and beta-glucan molecules accessible for enzymatic hydrolysis, which reduces viscosity, and any potentially slimy mouthfeel, and cuts the starch down into soluble dextrins and simple sugars that

increase sweetness. The resulting degree of polymerization (DP) is highly predictable based on factors including enzyme dose, time-temperature conditions, and substrate concentration, and can be quantified via HPLC. Glucose (DP1) is sweeter than maltose (DP2), and DP3-DP10 also impact the perception of sweetness (Pullicin,, *et al.*, Al 2017). Hence, sugar concentration (DP1 + DP2) alone does not completely predict sweet taste.

HOW OAT DRINKS ARE PRODUCED

Figure 1 shows the typical process flow for producing oat beverages. This process includes a liquefaction step when alpha-amylase and beta-glucanase enzyme activities solubilize the starch and reduce viscosity during heat treatment. BAN 480 L possesses both required enzyme activities. Liquefaction is typically followed by a saccharification step using a maltose or glucose producing amylase for sweetness and fine-tuning of mouthfeel. Amylases are the most common enzyme used in oat-based beverage creation as they enable producers to deliver the versatility consumers require, without the need for added sugar from another ingredient source.

TWO DIFFERENT WAYS TO OPTIMIZE SWEETNESS

Plain flavor milk-replacement beverages are typically formulated to match the sweetness of dairy milk. Similar, familiar sweetness eases adoption by consumers, who drink the beverages as is and add them to other popular beverages and foods, such as coffee and breakfast cereal. The desired sweetness in oat beverages can be achieved in different ways to suit the

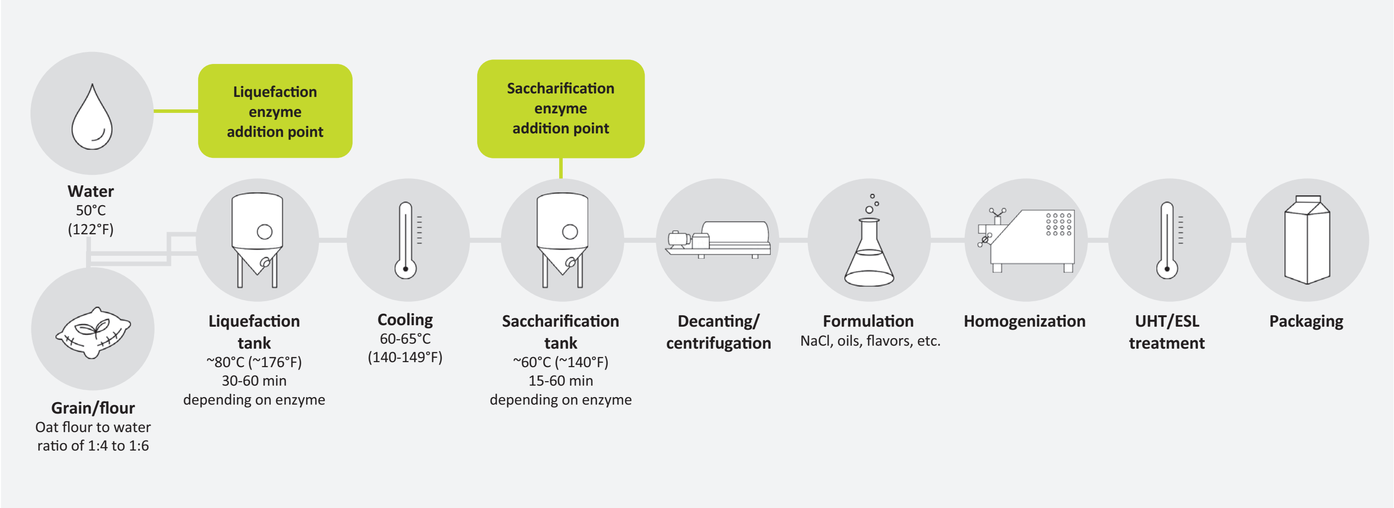

FIG 1. Production of oat drinks

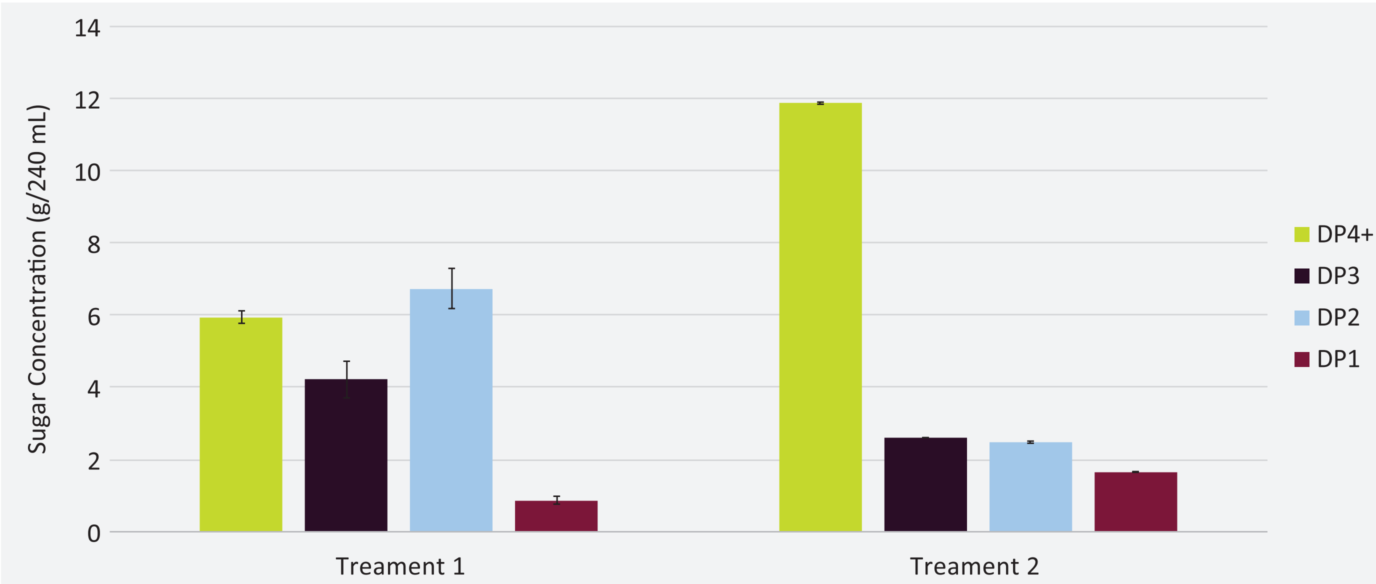

FIG 2. Comparison of carbohydrate composition

Use enzymes in oat drinks to:

- Adjust sweetness
- Optimize nutritional profile
- Improve yield
- Adjust mouthfeel and beverage viscosity
- Increase protein content

producer. The following case shows how two different ways of applying enzymes in the oat beverage process can create the same level of milk-like sweetness without significantly affecting the taste or mouthfeel.

Oat beverages based on the following two concepts were produced at lab scale using a Thermomix blender to heat up the solution and maintain a time-temperature profile. The beverages were then filtered through 200 µm mesh and formulated with added oil and salt. The carbohydrate composition (DP1-DP4+) was measured via HPLC. Dissolved solids, viscosity and pH levels were quantified. Descriptive sensory analysis was conducted at NC State University.

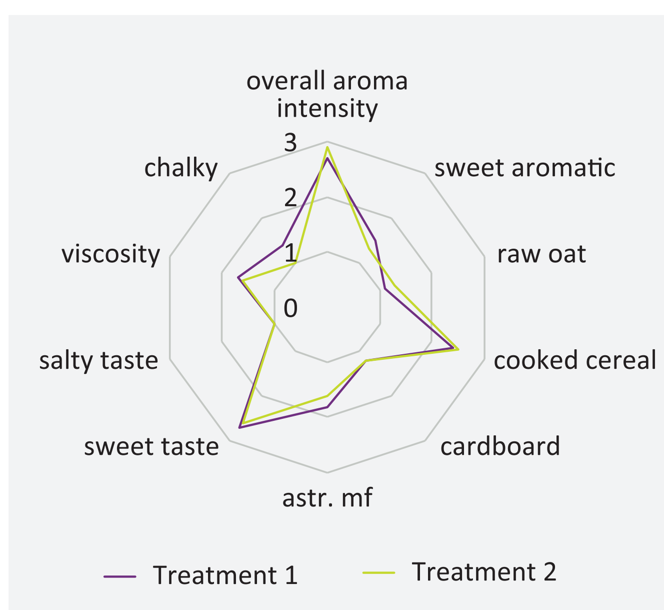

FIG 3. Sensory comparison

TABLE 1: Oat beverage concept comparison

Concept	Enzymes	Dissolved solids (%)	Viscosity (cP)	pH	Total sugar per serving (g/240 mL)	Sensory Sweet Taste
2-step hydrolysis, optimized enzyme dosage	Liquefaction: 0.2% BAN®480L Saccharification: 0.2% Fungamyl®800L	8.5-10	25-30	~6.5	8	2.7
Efficient 1-step process, reduced process time	2.0% BAN®480L				4	2.6

Concept 1: minimizing enzyme usage

The most common oat beverage formula is one based on maximizing the hydrolysis of the oat flour into maltose, glucose, and small molecular weight sugar and dextrins for a balance of optimal yield (soluble solids), mouthfeel, and mild sweetness. This concept is designed for minimum enzyme dosage by working close to the temperature optimums for the enzymes.

Concept 2: optimizing process efficiency

This second common concept is designed for greater process efficiency. This formula uses only Novozymes BAN® 480 L, but a high enough dose to generate the desired mild sweetness and mouthfeel in a single combined liquefaction and saccharification step. By combining the liquefaction and saccharification steps with no cooling, processors can benefit from improved asset utilization and process time.

SACCHARIFICATION AND SWEETNESS

Figures 2 and 3 compare the carbohydrate profile and sensory results of tests of the two concepts, respectively. The BAN + Fungamyl® combination in concept 1 yields low glucose and significant maltose. Application of a higher dose of BAN in concept 2 results in less simple sugar generation, but significant levels of maltotriose and other larger dextrins from DP3-DP10 (data not included), which are perceived as sweet. In other words, equivalent sweetness can be generated at a lower total sugar per serving.

SAME SWEETNESS IN TWO DIFFERENT WAYS

The two concepts were profiled by a trained sensory panel at the North Carolina State University Service Center, using a 0-to-15 point universal intensity scale for descriptors found relevant to the beverages (Meilgaard and others 1999; Drake and Civille 2003). They found that despite the differences in the enzyme treatments and resulting sugar and dextrin profile, the taste profiles are quite similar. Both concepts scored just above the sweetness of dairy milk at 2.3. Table 1 shows how the two concepts tested achieved comparable results in terms of sweetness, dissolved solids, viscosity and pH value, but concept 2 results in less simple sugar generation.

VERSATILITY THAT MATCHES PRODUCER AND CONSUMER REQUIREMENTS

The demonstrated concepts are just two of the many ways that enzymes can be used to create the oat beverages consumers require. Other enzyme classes beyond amylases can be used to increase the solubility of oat protein and improve beverage stability. Enzymes are versatile tools (see information box, page 12) to meet production requirements and achieve the claims that resonate most with consumers.

James Chapa, Scientist, Novozymes North America, has been with Novozymes since 2020, and has a background in Food Science research and development. He obtained a B.S. and M.S. in Food Science from NC State and Purdue University, respectively. At Novozymes, he works with plant protein applications in the Technical Services Food & Beverage group.

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Health benefits of mushrooms: Has their moment in medicine arrived?

Divya Yadav and Pradeep Singh Negi

- Edible mushrooms are considered a "hidden source of nutrients" and are classified as "white vegetables."
- Due to their nutritional benefits, mushrooms are used as a dietary supplement to boost human health.
- Consumption of mushrooms is also beneficial from a nutraceutical aspect as they are gluten-free, cholesterol-free, rich in protein, and contain polyunsaturated fats.

Mushrooms are widely appreciated as a culinary delicacy due to their distinct flavor and appealing texture. These edible members of the fungi family also have a high functional and nutritional value due to their organoleptic value and medicinal properties which traditional cultures have historically exploited to enhance human nutrition, improve health, and prevent or treat various diseases (Fig. 1).

The edibility of mushrooms is based on several factors, including the absence of toxic effects and their acceptable taste and aroma. Variations in strain, substrate, cultivation practices, growth conditions, aging, handling, storage, processing, and cooking procedures influence their nutritional and biologically active compound content. Many wild-grown mushrooms are also considered an ideal source of plant-based nourishment, as they are high in protein, carbohydrates, and essential minerals (with contents similar to those in eggs, meat, and milk) but low in calories. However, distinguishing edible and medicinal mushrooms is challenging. Since many common edible species have therapeutic potential,

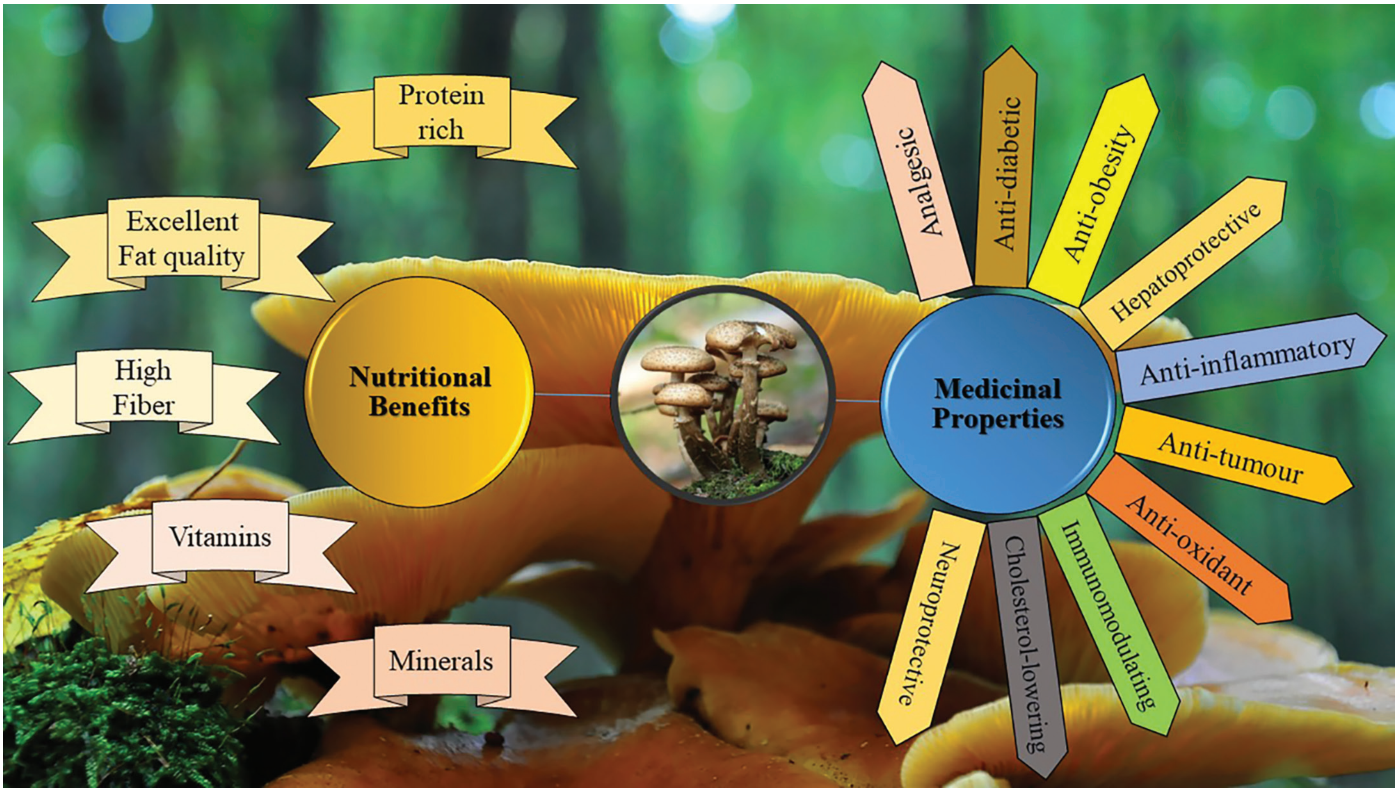

FIG. 1. Nutritional and medicinal properties of mushrooms

and several medicinal mushrooms are edible, mushrooms in general are considered a health-benefiting food and acknowledged by many to be a superfood.

Macrofungi and their bioactive compounds are used as meat substitutes, fermented non-alcoholic beverages, tonics, supplements, and spirit ingredients. The inclusion of newer varieties of mushrooms for commercial cultivation has exploded global mushroom trade in the last two decades, and development of innovative products from mushrooms will additionally positively affect economic growth. Their growing appeal as a meat substitute and increasing appeal as an alternative muscle protein will lead to further growth of the global mushroom market, which is currently being driven by an increase in the vegan population preferring a protein-rich diet. The benefits of mushroom cultivation and its diversified products on human welfare in the twenty-first century can be considered a "non-green revolution" worldwide.

Mushrooms are ideal for vegetarian diets since they provide all the essential amino acids required for healthy development along with a higher protein content than most vegetables. In traditional oriental medicine, edible mushrooms have long been used in natural hypercholesterolemic and anti-sclerotic diets. Mushroom proteins are also reported to be effective in the treatment of various gastrointestinal disorders.

MUSHROOMS ARE THE SOLE NON-ANIMAL DIETARY SOURCE OF VITAMIN D, MAKING THEM THE ONLY NATURAL VITAMIN D SOURCE AVAILABLE TO VEGETARIANS.

Mushrooms are also rich in digestible (trehalose, glycogen, mannitol, and glucose) and non-digestible (chitin, mannans, and beta-glucan) carbohydrates. The critical components of mushroom cell walls, chitin and beta-glucan, have diverse physiological functions. In addition, gut microbiota break down mushroom polysaccharides to release metabolites, such as short-chain fatty acids (SCFAs), which influence intestinal homeostasis. Consequently, mushrooms have potential as a significant source of a wide range of food ingredients and nutraceuticals to promote health.

The intense umami flavors in mushrooms decrease salt intake by 30–40%. Consequently, mushrooms can play a role in supporting the sodium reduction strategies of almost 100 countries around the globe (see Highlights from the US FDA's final guidance on sodium, *Inform*, January 2022, page 31)

Mushrooms are the sole non-animal dietary source of vitamin D, making them the only natural vitamin D source available to vegetarians (many wild mushrooms have more vitamin D than commercial mushrooms), and mushrooms contain a significant amount of other vitamins (B_1, B_2, B_{12}, C, and E).

The fat quality of edible mushrooms is excellent, despite their low lipid content. Mushrooms are ideal for individuals with higher blood cholesterol, as they are low in calories and fat yet high in vital fatty acids. Polyunsaturated fatty acids consti-

FIG. 2. Health benefits of mushrooms

tute a large portion of total fatty acids in mushrooms (which is considered beneficial for health), contributing to even more than 75 % of total fatty acids, mainly dominated by oleic and linoleic acids. Their fatty acid content positively influences lipid profiles in the blood. Ergosterol is the most abundant sterol synthesized by edible mushrooms and is well known for its antioxidant potential. Moreover, a diet high in sterols is beneficial in reducing cardiovascular disorders.

Mushrooms have been widely investigated for their anti-tumor, antioxidant, immunomodulating, radical scavenging, cholesterol-lowering, cardiovascular, antimicrobial, anti-inflammatory, hepatoprotective, detoxicating, anti-obesity, anti-diabetic, analgesic, and other therapeutic properties (Fig. 2). These properties are attributable to the bioactive compounds present in the mycelia and fruiting bodies of the fungi, such as polysaccharides, proteins, lipids, minerals, vitamins, and various other complexes.

These developments in nutrition and nutraceutical research has led to a surge in interest with respect to mushrooms' pharmacological potential over the past decade, with mushrooms serving as mini-pharmaceutical factories synthesizing compounds with remarkable biological effects. Although many of the mushrooms' therapeutic properties have been discovered, there is a paucity of knowledge on the characterization of their bioactive molecules and the molecular pathways that promote health. Hence more information is required to utilize this under-appreciated food as a medicinal food.

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Bio-based lubricants for a cleaner, safer world

Raj Shah and Kyle Lin

Each year, marine shipping alone leaks 37–61 million liters of lubricant oils from stern tubes and other operational discharges, polluting the aquatic environment [1]. This is only a small fraction of the total amount of lubricants that enter the environment on an annual basis. According to recent estimates, 30% of lubricants consumed end up in the ecosystem [5]. They leak into the soil and groundwater, where they cause serious contamination and reduce the quality of the water we drink. They emit toxic compounds into the atmosphere, poisoning the air we breathe.

- **Petroleum based oils made from mineral and synthetic base oils are used in more than 70% of the lubricants today.**
- **An estimated 30% of the lubricants consumed end up in the ecosystem, where they pollute aquatic environments, leak into groundwater, and emit toxic compounds into the atmosphere.**
- **In contrast, today's biolubricants are extremely biodegradable and nontoxic, and have properties that surpass those of petroleum-based oils.**

In contrast, biolubricants from plants, animals, vegetables, animal fat, and animal oils are more renewable and extremely biodegradable and nontoxic, having little to no environmental impact. Today's biolubricants also have properties that surpass those of petroleum-based oils, such as high flash points, constant viscosity, and characteristics that make them generally safe to handle.

STANDARDS

Biolubricants are heavily monitored. To be categorized as a biolubricant, oils must be at least 90% biodegradable, and greases must be 75% biodegradable (Fig. 1). In addition, the non-biodegradable components must be non-harmful to the environment to be labeled an "environmentally acceptable lubricant" (EAL) as well as a "bio-lubricant" by the EPA [3]. Lubricants with both claims on the label have achieved a set standard for biodegradability, toxicity, and bioaccumulation potential. Biodegradability measures the speed at which a lubricant breaks down into harmless components—a critical measure as waste products continue to accumulate in the natural world.

Lubricants that have positive environmental properties but have not met these high standards are called environmentally friendly lubricants (EFL). While EFL lubricants are promoted as being environmentally friendly, they are not completely friendly, as they still pose some threat, albeit minimal, to the natural environment [4]. A lubricant can be classified as an EFL if it is partially degradable, if it demonstrates low toxicity, or even if it is only partially made from biomass.

EALs need to be made up of base oils that are themselves biodegradable, which is why they are regarded so highly. Lubricants can be tested using standard methods, such as the OECD 301B or F, which provide methods for biodegradation testing for lubricants. The test method consists of observing the lubricant in the presence of water or microorganisms to see how well it breaks down [13].

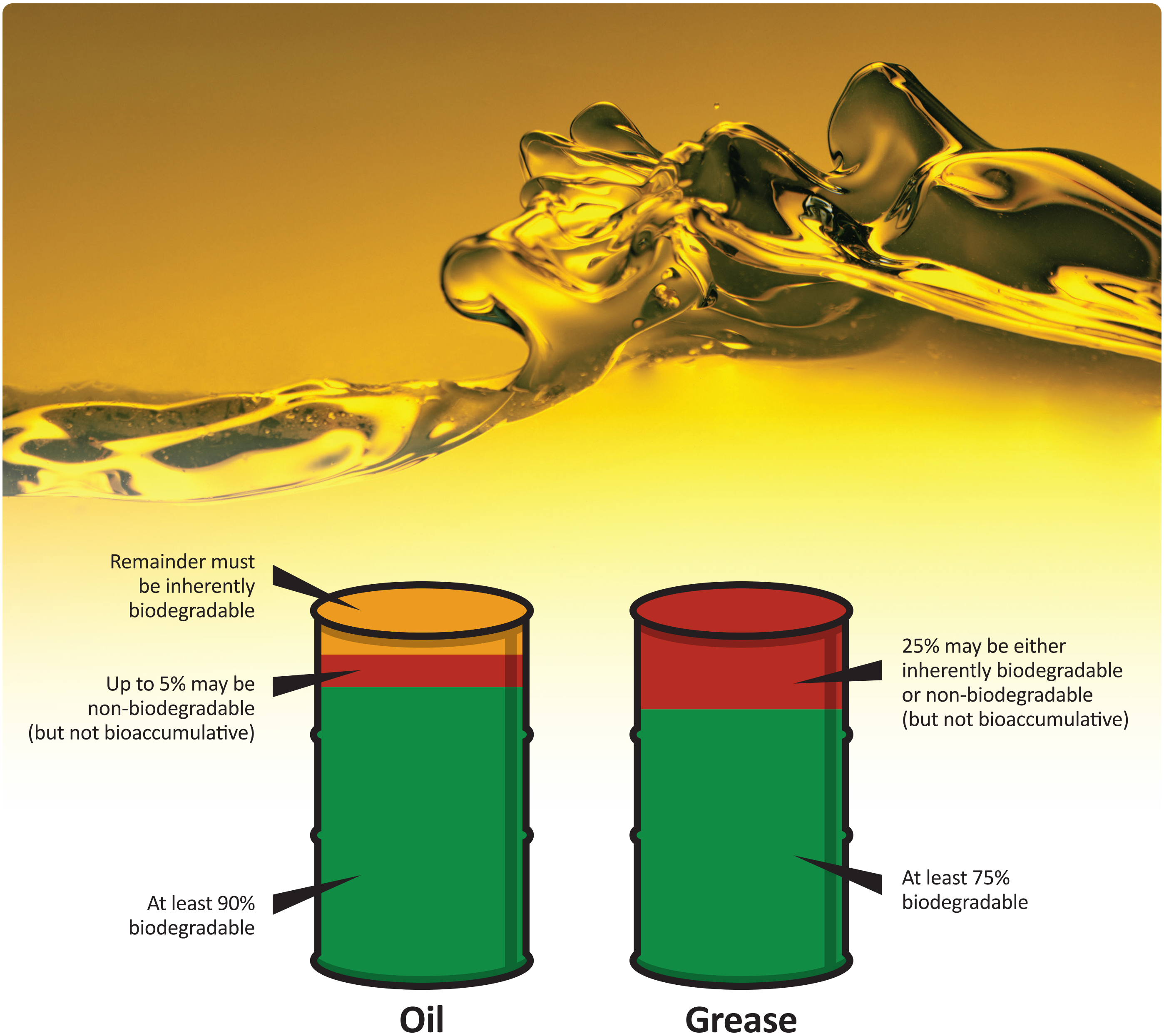

FIG. 1. Strict guidelines for the classification of a biolubricant [3]

Additionally, OECD has defined biodegradability with the following terms: readily biodegradable, ultimately biodegradable, inherently biodegradable, and non-biodegradable. It is generally understood that biodegradability is degradation with the OECD 301 test methods [12]. The breakdown of the terms is shown in Table 1.

TABLE 1. Definitions of terms related to biodegradability

Readily Biodegradable	≥ 60% and within 10 days
Ultimately Biodegradable	≥ 60% within 28 days
Inherently Biodegradable	20%-60% in 28 days or longer
Non-Biodegradable	≤ 20% in 28 days

While most mineral oil-based lubricants have a low biodegradation of less than 40%, EFL's can degrade by at least 60% within 28 days [12]. These high standards have been put out in hopes that lubricants can be used with more caution and better alternatives for the environment's safety can be considered.

BENEFITS OF BIOMASS-DERIVED LUBRICANT BASE OILS

Plant oils are an example of a biolubricant base and have proven to be suitable for lubricants. The chemical structure of plant oils gives them certain properties that allow them to have a higher lubricity for lower friction loss, higher shear ability, faster biodegradation, and higher viscosity indices. This makes them potentially very useful in many situations [6].

As mentioned before, due to the biolubricant coming from natural and obtainable materials, it is sustainable, lowering dependence on limited fossil fuels and significantly reducing environmental impact from lubricants. In a study conducted of two biolubricants synthesized with 2-theyl-1-hexanol and 1-octanol, the half-lives of the biolubricants were found to be about 26 and 20 days respectively. In comparison, mineral lubricants have a half-life that is about 114 to 231 days [9]. The two biolubricants were not quite as biodegradable as the vegetable oil base (fresh castor oil) used to create them, but their biodegradability was a huge improvement from traditional mineral oils.

WHILE PETROLEUM-BASED LUBRICANTS ARE STILL THE PREFERRED LUBRICANT FOR LOW-TEMPERATURE PERFORMANCE AND OXIDATIVE STABILITY, METHODS AND MATERIALS CONTINUE TO BE EXPLORED SO THAT BIO-BASED LUBRICANTS WILL SEE MORE USE AS THE PREFERRED LUBRICANT.

Vegetable oils have been used in all sorts of industries for years. Some crude vegetable oils have passed wear tests (e.g., ASTM D2882 and ASTM D2271) in their natural form without extra additives, cementing their ability to function at the same level, and sometimes better than, traditional petroleum-based lubricants [2]. For example, soybean oil typically has a very high viscosity of 223 on the viscosity index compared to 90–100 for most petroleum oils. Vegetable oils also have very high flash points. Soybean oil has a flash point about 610°F (236°C) , while the flash points of mineral oils are usually about 392°F (200°C) [2].

Biolubricants excel with respect to health and safety issues as well. Their high flash points may improve the safety of workers by decreasing fire risk, and better skin compatibility would be less likely to cause dermatological-related conditions. [5]. The concern for worker safety has increased the use of biolubricants in industries beyond forestry and agriculture. They have been increasingly used in metalworking fluids, automotive manufacturing, and general manufacturing sectors, to name a few [7].

CHALLENGES

Biolubricants still pose challenges. Because plant oils contain unsaturated fatty acids, which are inherently unstable, they have a low oxidative stability, meaning that the oil will oxidize quickly, becoming thick and polymerizing to a plastic-like consistency [2]. Oxidation can result in sludge formation, corrosion, rust formation, and viscosity increase, all of which could bring unexpected damage to machinery and halt the process the lubricant is used to assist [10]. In addition, plant oils still do not have the thermal stability and viscosity ranges that give petroleum-based lubricants their high performance. Plant oils could be modified to improve these properties, but such modifications would be cost-prohibitive [8].

With such a small market for biolubricants, an estimated of 39.6 million tons in 2016, the costs are still extremely high [7]. Also, with such niche sectors that the biolubricants are used in such applications as forestry, many still prefer the conventional petroleum-based lubricants. Biolubricants are created in a process called pyrolysis, in which the biomass base is heated in the absence of oxygen, producing an oil like liquid. It can then be further refined into other biolubricants to create a lubricant to fulfill a specific need [4]. This process is very expensive compared to the prices of fossil carbon. As a result, it's undesirable for industries to purchase such a premium when petroleum-based lubricants are available. However, once the negatives of biolubricants are improved, they will become even more of an alluring option given all the benefits that they could bring.

For example, agriculture and farming today can be adapted to producing more specific products, such as those that can be engineered to create a desired lubricant. A recent advance in biotechnology has allowed DuPont Technology to develop a soybean seed that consist of more than 83% oleic acid as compared to about 20% of oleic acid in conventionally used soybean oil. The oil has shown about 30 times more oxidative stability and viscosity stability in hydraulic pump tests, and as a result, may become the standard for lubricant base oils for biolubricants [2].

In another study, it was found that high-oleic soybean oils with oleic content enhanced up to 65% had many improvements to previously noted downsides. One such improvement was its oxidative stability. With the rotating pressure vessel oxidation test (ASTM D2272), where a sample is oxidized and rotated in a pressure vessel until a specified drop in pressure, it was found that this high-oleic sample soybean oils lasted up to 194 and 153 minutes, completely outclassing a low-oleic sample at 45 minutes. While this was still not up to mineral oils, in which Adam found to last 600 minutes, it is still a vast improvement [14].

FUTURE

Spills and leakages are inevitable. As oil continues to leak into nature, the planet continuously gets polluted. While legislation is implementing more rules and guidelines for the use of lubricants, the pace needs to be sped up to limit the damage done. The bio-based lubricants have benefits that must be made known, and problems that need to be addressed. However, the future is bright with the promising jumps for biolubricants. Some issues with biolubricants are being solved at a brisk pace, allowing these lubricants to be improved for the public use.

So, while petroleum-based lubricants are still the preferred lubricant for low-temperature performance and oxidative stability, methods and materials continue to be explored so that bio-based lubricants will see more use as the preferred lubricant. While prices are exorbitant for biolubricants, once consumption sees more growth—and it will see more growth considering the deterioration of the earth—lubricant manufacturers will be able to produce these products more economically. Biomass based lubricant oils need to be kept in the limelight, so that the energy independent and clean future will come closer to fruition.

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Chemistry and functionality of cold-pressed macadamia nut oil

Tafadzwa Kaseke, Olaniyi Amos Fawole, and Umezuruike Linus Opara

- **Consumers prefer cold-pressed macadamia nut oil (CPMO) over solvent-extracted and refined oil because of its exceptional quality attributes and safety.**
- **CPMO has good oxidative stability and a fatty acid composition that allows for its diverse application in the food, cosmetic, nutraceutical, and pharmaceutical industries.**
- **This article describes the chemical properties, health benefits, and applications of CPMO. It is a shortened and republished version of an article that was originally published in** ***Processes 10*****(1): 56, 2022. The complete references can be found at https://doi.org/10.3390/pr10010056.**

Driven by its health benefits, global macadamia nut production has steadily increased in the past decade, reaching 60.057 metric tons, MT, (kernel basis) in 2019, which represented a 2% increase from the previous year (Fig. 1).

The largest producers of macadamia nuts are South Africa (29%) and Australia (22%). Together they contribute 51% of the global production (FIG. 2A), while the chief importers of macadamia nuts are the United States, Germany, Netherlands, China, and Japan, which import over 70% of the global share (FIG. 2B). Despite being the world leader in macadamia production, the local market in South Africa only consumes 2% of the nut, with the United States and Europe together taking up more than 44% of the total production.

The continued increase in demand for unrefined oil and consumer health consciousness has driven the processing of macadamia nuts into

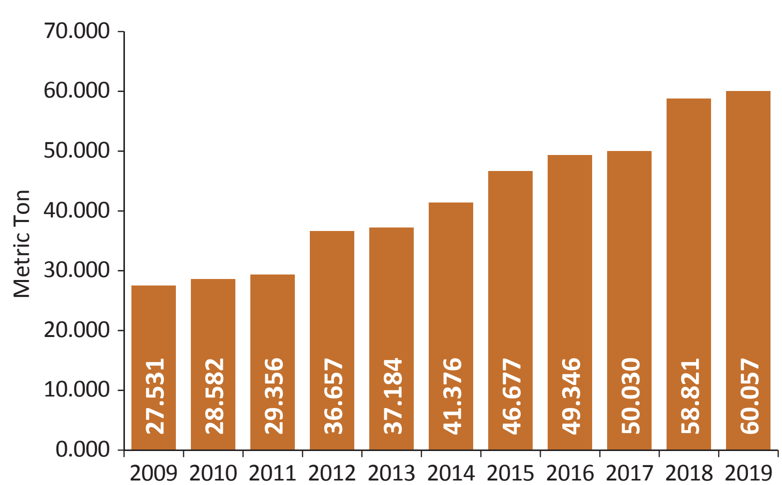

FIG. 1: Global production of macadamia nut (2009–2019). Adapted from: International Nut and Dried Fruit Council (https://www.nutfruit.org/industry/technical-resources).

oil. Depending on the extraction method employed, macadamia nut oil can be marketed as cold-pressed or virgin oil (CPMO). CPMO is a desirable raw material for functional food, pharmaceutical, and cosmetics formulations.

COLD PRESSING AND SEED PRETREATMENT

Typically, at the commercial level, two oil extraction methods are available: solvent extraction and pressing. Solvent extraction is more suitable for seeds with a lower oil content (<20%), while pressing is suitable for seeds with higher oil content, such as macadamia nuts. Nevertheless, a significant amount of oil remains trapped in the seed cold-pressed oil cake, so the method produces a low oil yield. In one study using a cold press, the oil yield (30–40%) was 25–50% lower than that of solvent-extracted oil (40–60%). The results suggest that the pressed meal still contained a significant quantity of oil. In another study, cold-pressing left a residual oil content of approximately 52% in a defatted macadamia meal. Despite the high oil content in macadamia nuts (69–78%), two other researchers only managed to extract oil ranging between 23 and 26%. Moreover, the pressed meal contains substantial amounts of bioactive compounds such as phenolics (approx. 0.5 mg/g on a dry basis).

To extract the residual oil, the pressed meal can be further subjected to solvent extraction. However, the use of organic solvents such as hexane, petroleum ether, benzene, or pentane in food extractions is not recommended due to their negative health effects on humans and the environment. In addition, plant security issues, higher operational costs, poor quality products due to high temperature, and residual solvent are some of the disadvantages of using organic solvents. In

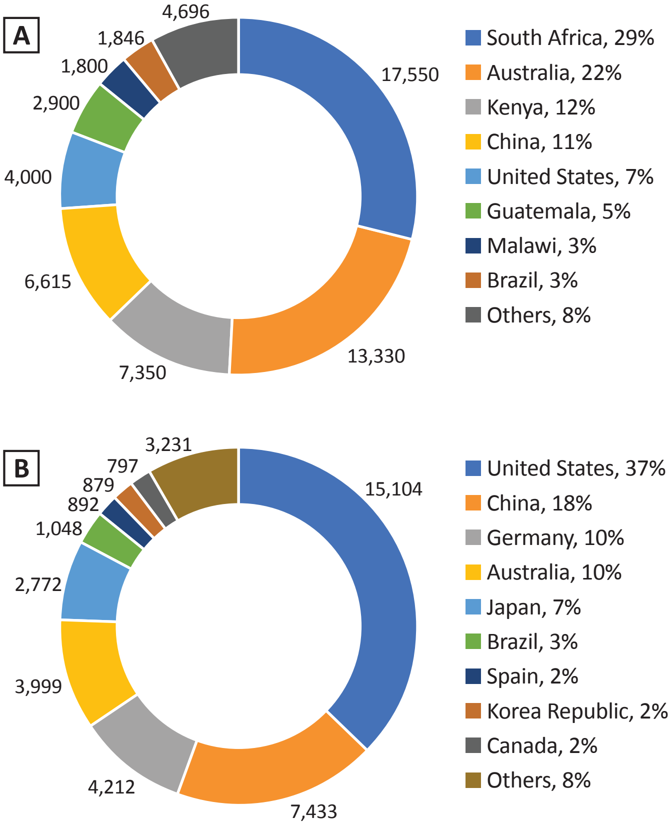

FIG. 2. (A) World estimated macadamia nut production (metric ton) and (B) consumption (metric ton) in 2018. Adapted from: International Nut and Dried Fruit Council (https://www.nutfruit.org/industry/technical-resources).

TABLE 1. Fatty acid composition (%) of cold-pressed macadamia nut oil

Fatty Acid	Cicero *et al.*	Madawala *et al.*	Gong *et al.*	Gliszczynska-Swigło *et al.*	Ribeiro *et al.*	Yuenyong *et al.*
Myristic	0.91	0.7	0.7	ND	0.34	ND
Palmitic acid	6.84	8.1	7.6	8.31	8.66	12.02
Palmitoleic acid	9.68	18.1	18.33	20.9	18.26	13.38
Margaric acid	0.12	ND	ND	ND	ND	ND
Stearic acid	3.39	3.6	2.98	3.4	2.82	2.78
Oleic acid	50.65	54.6	52.37	58.12	63.56	58.69
Linoleic acid	8.63	3.3	1.89	2.51	1.43	ND
Linolenic acid	14.59	0.4	0.16	0.24	2.38	ND
Arachidic acid	2.01	2.7	2.26	2.54	ND	ND
Gadoleic acid	1.13	2.4	1.29	ND	2.53	ND
Behenic acid	0.73	ND	ND	0.74	ND	ND
Lignoceric acid	0.56	ND	ND	ND	ND	ND
SFA	14.56	15.1	12.13	15.96	11.81	14.8
MUFA	61.49	78.8	70.8	79.02	84.35	72.07
PUFA	23.22	3.7	3.04	5.02	3.81	ND
UFA/SFA ratio	5.82	5.46	6.09	5.23	7.46	4.87

SFA—saturated fatty acid; MUFA—monounsaturated fatty acid; PUFA—polyunsaturated fatty acid; UFA—unsaturated fatty acid; ND—not detected.

comparison, mechanical pressing is simpler, safer, and requires less capital investment.

Two types of mechanical pressing methods are common: cold pressing and hot pressing. The literature has reported that the maximum temperature of cold-pressed oil ranges between 30–50°C, which preserves its nutritional quality. Three main stages are involved in cold pressing: seed defatting, seed fragmentation, and seed conditioning. Seed defatting is uncommon at the commercial level due to technical issues, but it enhances the quality of the oil by reducing the concentration of chlorophyll and other substances such as metals and pesticides. This produces oil with a brighter color and high resistance to oxidation. Seed fragmentation enlarges the oil spillage by destroying seed structures and hulls. It is noteworthy to indicate that this process should be immediately followed by pressing, as it may expose the oil to oxidation. Seed conditioning, which involves heat pretreatment at 100°C and moisturizing to the optimal humidity, is vital to improving the oil yield. Seed condition is essential for seeds with low fiber content, such as macadamia nuts, to prevent the machine from producing an oily paste instead of oil and cake. CPMO may be physically purified through filtration, sedimentation, or centrifugation processes. The packed oil may be further flushed with nitrogen to prevent oxidation and the generation of odoriferous compounds. To this effect, the nutty flavor, and minor nutrients like vitamin E, phytosterols, and polyphenols are well preserved. The shelf life of CPMO stored under appropriate storage conditions (25°C and low oxygen) ranges from 9–15 months.

Cold-pressed oils are produced using either a hydraulic or screw press. The hydraulic press operates in a non-continuous mode at a pressure ranging from 11.376—12.755 kPa and uses liquid (oil) as a medium to squeeze out the oil from the seed. This method produces a lower oil yield but of higher quality than screw press. On the other hand, the screw press operates by applying a high shear force to the material to press out the oil. As a result of frictional heat that may be produced during pressing, a cooling system may be attached to it, to avoid degradation of heat-labile bioactive phytochemicals. The critical parameters that affect cold-pressed oil quality include the seed characteristics (moisture content, oil content, and type of seed), feed rate, temperature, rotation speed, die diameter, and seed pretreatment. To circumvent the low oil yield problem in cold pressing, seed pretreatment has become an appropriate and valuable step in cold pressing. Conventionally pretreatment of seeds prior to oil extraction includes dehulling, size reduction, breaking, grinding, and thermal and non-thermal treatment to debilitate the cell coats and enhance oil extraction during pressing. The application of microwaves to macadamia nuts prior to oil extraction has gained research interests due to its technical and economic benefits. The microwaves generate high-frequency waves, which break the cells by shock induction. The waves penetrate the material and vibrate the molecules, provoking a rapid heating and subsequent rupture of the cells, which may help to improve oil extraction efficiency. In one study, microwave pretreatment of macadamia nut improved the oil extraction efficiency of a hydraulic press by more than 50%. The authors further highlighted that combining microwave heating with hydraulic pressing produced macadamia nut oil with better oxidative stability.

TABLE 2. Comparison of fatty acid composition (%) of cold-pressed macadamia nut oil with cold-pressed oil from selected tree nuts

Tree Nut Oil	Fatty Acid								Reference
	Palmitic Acid	Stearic Acid	Arachidic Acid	Palmitoleic Acid	Oleic Acid	Erucic Acid	Linoleic Acid	Linolenic Acid	
Almond	19.21	2.87	ND	ND	49.08	ND	21.43	ND	Yuenyong *et al.*
Cashew	14.61	8.75	0.43	ND	62.73	ND	13.27	ND	
Coconut	21.47	5.56	ND	37.52	ND	14.85	10.73	ND	
Hazelnut	7.95	2.11	ND	ND	73.19	ND	16.63	ND	
Pistachio	10.73	0.3	ND	1.52	43.97	ND	40.26	ND	
Walnut	12.5	1.57	ND	26.24	ND	ND	47.19	10.73	
Macadamia	12.02	2.78	ND	13.38	58.69	8.18	ND	ND	
Almond	4.4	2.3	0.5	ND	1.5	-	25.1	0.5	Madawala *et al.*
Hazelnut	5.3	2.4	ND	0.3	1.7	-	13.2	0.4	
Walnut	7	3	ND	ND	0.9	-	60.1	10.4	
Macadamia	8.1	3.6	2.7	18.1	3.7	-	3.3	0.4	
Almond	5.59	1.27	0	0.45	64.87	-	21.84	0.03	Gong *et al.*
Hazelnut	5.98	2.95	0.09	0.18	71.89	-	9.89	0.2	
Pecan	6.27	2.36	0.12	0.11	55.55	-	31.08	31.08	
Pine nut	3.74	2.12	0.39	0.11	31.79	-	31.75	2.29	
Pistachio	10.32	1.16 6	0.06	1.1	53.62	-	28.85	0.7	
Walnut	6.4	2.41	0.05	0.04	13.9	-	49.84	9.41	
Macadamia	7.6	2.98	2.26	18.33	52.37	-	1.89	0.16	
Brazil nut	15.03	10.51	0.28	0.33	40.2	-	33.33	0.06	Gliszczynska-Swigło *et al.* [39]
Hazelnut	5.83	2.6	0.12	0.2	83.94	-	6.88	0.15	
Almond	6.54	1.68	0.09	0.51	66.56	-	24.31	0.02	
Macadamia	8.31	3.4	2.54	20.9	58.12	-	2.51	0.24	
Walnut	7.1	2.6	0.1	0.1	18.4	-	59.7	11.2	Prescha *et al.* [43]
Macadamia	8.2	3.3	2.7	18.1	58.9	-	3.5	0.5	

ND—not detected; -—not tested in the respective experiment.

Fatty acid and triacylglycerol profile of cold-pressed macadamia nut oil

Triacylglycerols are the major component of the neutral lipids in CPMO, accounting for 87% of total neutral lipids. The primary triacylglycerol components. The profiles and relative concentration of the triacylglycerols from CPMO did not vary much from that of commercial macadamia nut oil. They included triolein (OOO: 24.0%), dioleoyl-palmitoleoyl-glycerol (OOPo: 21.6%), and dioleoyl-palmitoyl-glycerol (OOP: 14.7%). Other triacylglycerols present in CPMO, but in small quantities are dioleoyl-dipalmitoyl-glycerol (OPPO) (8.51%), oleoyl-dipalmitoleoyl-glycerol (OPoPo) (6.7%), dioleoyl-arachidoyl-glycerol (OOA) (3.69%), dioleoyl-linoleoyl-glycerol (OOL) (2.31%), palmitoyl-dipalmitoleoyl-glycerol (PPoPo) (1.78%), palmitoyl-oleoyl-stearoyl-glycerol (POS) (1.51%), and palmitoyl-oleoyl- arachidoyl-glycerol (POA) (1.1%). Monoacylglycerols and polar lipids are found in minor quantities, representing 1 and 3%, respectively.

Macadamia nut oil is acknowledged as one of the healthiest tree nut oils due to its unique fatty acid profile, characterized by higher monounsaturated fatty acids (MUFAs) accounting for more than 70% of the total fatty acids. CPMO is lower in saturated fatty acids (SFA) (<16%) and polyunsaturated fatty acid (PUFA) (<5%), so the oil has great oxidative stability and longer shelf life. A review of the fatty acid profiles of CPMO in presented in Table 1. Most of the studies reported that PUFAs and saturated fatty acids (SFAs) in CPMO range from 3–4% and 12–16%, respectively. However, one author reported relatively higher levels of PUFAs (23.22%). The differences could be attributed to variation in cultivar, growing conditions, harvesting time, degree of ripeness, among other factors. The unsaturated fatty acids (UFAs) to SFAs (5–7%) ratio in CPMO is similar to those in other cold-pressed oils such as grapeseed oil (6%); however, the quality of the unsaturated fatty acids varies. Oleic acid (51–64%) represents the most abundant fatty acid in CPMO, followed by palmitoleic acid (10–21%) and palmitic acid (7–12%). The literature reports that a higher intake of MUFA is associated with low incidences of coronary heart diseases, colon, breast, and skin cancer. Therefore,

TABLE 3. Comparison of fatty acid composition (%) of cold-pressed, solvent, and supercritical carbon dioxide extracted macadamia nut oil

Fatty Acid	Cold-Pressed			Solvent Extracted			Supercritical Carbon Dioxide Extracted	
	Rodrigues *et al.*	Madawala *et al.*	Prescha *et al.*	Navarro and Rodrigues[a]	Kaijser *et al.*[b]	Derewiaka *et al.*[c]	Chang *et al.*	Zhu *et al.*
Myristic	0.98	0.7	0.8	0.7	0.96–1.84	0.9	ND	ND
Palmitic acid	9.38	8.1	8.2	8.43	8.41–11.13	12.1	11.8	1.93
Palmitoleic acid	19.28	18.1	18.1	17.1	16.86–33.75	15	16	15.38
Margaric acid	ND	ND	0.1	ND	ND	ND	ND	ND
Stearic acid	3.4	3.6	3.3	3.9	1.49–3.19	5.2	5.5	4.18
Oleic acid	59.76	54.6	58.9	63.06	40.55–59.01	59.9	58.6	55.62
Linoleic acid	2.03	3.3	3.5	1.74	2.63–4.47	1.9	ND	1.55
Linolenic acid	0.14	0.4	0.5	ND	0.17–0.20	ND	ND	ND
Arachidic acid	2.56	2.7	2.7	2.93	1.23–2.06	3	3.73	ND
Gadoleic acid	2.48	2.4	2.4	2.2	1.36–2.63	2	2.64	1.89
Behenic acid	ND	ND	ND	ND	0.39–0.61	ND	ND	ND
Lignoceric acid	ND	ND	ND	ND	0.11–0.19	ND	ND	ND
SFA	16.32	15.1	15.1	15.96	13.23–17.81	21.2	21.08	6.11
MUFA	81.52	75.1	79.4	82.36	72.70–82.46	76.9	77.24	72.89
PUFA	2.17	3.7	4	1.74	2.83–4.67	1.9	0	1.55
UFA/SFA ratio	5.13	5.22	5.52	5.27	4.89–5.71	3.72	3.66	12.18

SFA—saturated fatty acid; MUFA—monounsaturated fatty acid; PUFA—polyunsaturated fatty acid; UFA—unsaturated fatty acid; ND—not detected. [a] Oil was extracted using ethanol; [b] Oil extracted using hexane; [c] Oil was extracted using petroleum ether.

from a health and nutrition perspective, high levels of oleic acid in vegetable oils are desirable. Structurally, oleic acid is a more stable unsaturated fatty acid compared with other unsaturated fatty acids such as linoleic acid. Other fatty acids in CPMO in smaller amounts (0.1–2.5%) include stearic acid, linoleic acid, linolenic acid, arachidic acid, malic acid, behenic acid, gadoleic acid, heptadecanoic acid, lignoceric acid.

Linoleic acid and linolenic acid, also referred to as omega-6 fatty acid (Ω6) and omega-3 fatty acid (Ω3), respectively, are two essential fatty acids crucial in the maintenance of physiological functions of the human body. The Ω6/Ω3 ratio is valuable in explaining the effect of dietary PUFAs on the pathogenesis of cardiovascular diseases, cancer, inflammatory, and autoimmune disorders. Generally, a high Ω6/Ω3 ratio is regarded as harmful to human health, whereas a value around 1 is considered healthier and protective against such chronic diseases. An unbalanced Ω6/Ω3 ratio that is in favor of omega-6 PUFAs contributes to the prevalence of atherosclerosis, obesity, and diabetes. One author reported a Ω6/Ω3 ratio of 1.69 in CPMO, indicating a healthy ratio, important in the prevention and management of obesity. Stearic acid is a saturated fatty acid with unique functional properties related to the reduction of LDL cholesterol levels in humans. Behenic acid, another saturated fatty acid present in trace amounts in CPMO, has low bioavailability and, therefore, causes less effect on cholesterol content in humans.

The fatty acid composition of CPMO with cold-pressed oil from almond, hazelnut, pecan, pine nut, pistachio, and walnut were compared. The authors reported that CPMO contained higher palmitoleic acid and stearic acid levels than other tree nut oils. Except for cold-pressed oil from walnut (14%) and pecan (32%), all the other cold-pressed tree nut oils contained high levels of oleic acid (>50%). Similar findings were reported by other authors. This indicates that tree nut oils are good sources of oleic acid, a suitable raw material for formulating plasma cholesterol reduction diets. CPMO contains lower linoleic acid and linolenic acid levels compared with cold-pressed oil from other tree nuts. Among the cold-pressed tree nut oils, walnut exhibited the best concentration of these essential fatty acids (Table 2). One study investigated the effect of seed microwave heating (maximum power, 2450 MHz, 1 min) on CPMO and reported an insignificant effect on the linoleic and linolenic. The results suggest increasing CPMO yield through microwave pretreatment of the seed for financial benefit without altering the essential fatty acid profiles.

It is generally agreed among researchers that the extraction method may not significantly affect the fatty acid profile of seed oil. The fatty acid composition of CPMO was compared with that of macadamia nut oil obtained by solvent extraction (Table 3). The relative percentages of SFAs, MUFAs, PUFAs, and individual fatty acids of CPMO did not differ much from the solvent-extracted macadamia nut oil, indicating that the fatty acids profile of macadamia nut oil may not be affected by the extraction method.

OTHER COMPOUNDS

CPMO is not a significant source of tocopherols or squalene, but its total phytosterol content ranged between 0.78 and 2.57 mg/g oil and was higher than the total phytosterol content of cold-pressed almond, walnut, and hazelnut oil (0.55 and 2.05 mg/g oil). Nevertheless, the total phytosterol content was lower than that of other cold-pressed tree nut oils (pecan, pine nut, and pistachio). Phytosterols are plant-based structures analogous to mammalian cholesterol. They contain an identical ring structure as cholesterol but differ in the side chain at the carbon 24 positions of unsaturated double bonds and differ in stereochemistry around chiral carbon. It has been reported that phytosterols can reduce intestinal cholesterol absorption due to the displacement of cholesterol in micelles. Their consumption at doses between 1.5 and 3 g/day can efficiently decrease LDL cholesterol by up to 15%. Cold-pressed plant oil contains a substantial amount of phytosterols, while most of the phytosterols in seeds are degraded during the refining process. One author reported that more than 40% of phytosterols could be lost during the oil refining processes; therefore, cold-pressed oil could be an excellent source of phytosterols.

The main phytosterol in CPMO was beta-sitosterol (0.66–2.11 mg/g) followed by campesterol (0.07.0–0.16 mg/g), avenasterol (0.04–0.29 mg/g), and stigmasterol (0.001–0.02 mg/g). Being the predominant phytosterol, most of the health benefits of phytosterols are contributed by beta-sitosterol, which has been reported to be effective in reducing serum cholesterol and LDL cholesterol levels. The beta-sitosterol content of CPMO was 1.1–3.4 times higher than those in pine nut oil, black currant seed oil, hemp seed oil, dill seed oil, parsley seed oil, milk thistle oil, and black cumin seed oil.

The total phenolic content in CPMO was 3–24 times higher than that of cold-pressed oil from almond nut, hazelnut, Brazil nut, and pecan nut. In the same study, CPMO showed significantly higher levels of total phenolic compounds (2–15 fold) than refined oil from canola, corn, soya bean, and sunflower).

Phenolic compounds contribute not only to the taste of vegetable oil but also to its oxidative stability. Moreover, they have been reported to have multiple biological effects, including antioxidant activity through breaking the oxidation chain reaction or scavenging the free radicals depending on their chemical structures. The total phenolic content of CPMO analyzed using ultra-high-performance liquid chromatography-mass spectrometry (UHPLC) was 2.36 microgram/g.

A study comparing the mineral content of CPMO with cold-pressed oil from olive, Brazil nut, grapeseed, canola, avocado, coconut, pequi, and palm seed found that CPMO exhibited higher sodium, magnesium, potassium, and calcium levels ranging between 1.11–13.91 microgram/kg. These elements play crucial roles in many physiological functions of the human body, including preventing diseases such as hypertension, heart attack, and various gastrointestinal cancers.

Similar to cold-pressed oil from grapeseed, CPMO was high in iron (10.20–11.48 microgram/kg), a prooxidant element, which was 2 to 5-fold higher than the rest of cold-pressed oils. Nonetheless, the reported iron levels were within the maximum permissible limits (5.0 mg/kg) of the Codex Alimentarius Commission standard for cold-pressed vegetable oil (Codex-Stan 210–1999) and were considered too low to cause significant oil deterioration.

HEALTH-PROMOTING EFFECTS OF MACADAMIA NUT OIL

Data regarding the health effects of CPMO is limited. Nevertheless, based on the high levels of MUFAs (oleic acid and palmitoleic acid) the potential health-promoting benefits of CPMO have been emphasized extensively. CPMO is envisaged to possess better health properties than refined or commercial macadamia nut oil. Despite the lack of data on CPMO, *in vivo* studies using commercial macadamia nut oil have demonstrated that the oil lowers serum lipids or lipoproteins, thereby reducing cardiovascular disease risk. Therefore, macadamia nut oil can be used as a supplement to offer a cholesterol-lowering effect.

The influence of commercial macadamia nut oil (Baxter Healthcare, Deerfield, Illinois, USA) on the plasma and liver fatty acid level, hepatic lipogenesis activity, hepatic stearoyl-CoA-1 desaturase activity, and hepatic elongase activity was evaluated using mice. C57BL/6 male mice, which were 6 weeks old were fed with macadamia nut oil after diets that varied in the type of carbohydrates (starch, sucrose, and fructose). The authors reported that macadamia nut oil prevented steatosis and prevented an increase in saturated fatty acids and lipogenesis as well as stearoyl-CoA-1 desaturase activity. Another study had similar findings after feeding 96 male Wistar rats (9–10 weeks old; 336 ± 2 g) with diets enriched with commercial macadamia nut oil (3%) (Proteco Gold Pty. Ltd., Kingaroy, Queensland, Australia) for 8 weeks. The decrease in plasma total cholesterol, plasma markers of liver damage, trans fatty acids in the heart, liver, and skeletal muscle, stearoyl-CoA desaturase-1 activity index, and normalization of systolic blood pressure were attributed to oleic acid from the macadamia nut oil.

Stearoyl CoA-1 desaturase catalyzes the rate-limiting step in the production of MUFA in the human body. It has been reported that high stearoyl-CoA-1 desaturase expression may cause metabolic diseases such as obesity and insulin resistance. In addition, a complete loss of stearoyl-CoA-1 desaturase expression has been implicated in liver dysfunction and inflammatory diseases such as dermatitis, atherosclerosis, and intestinal colitis. Attenuation of the increase in inflammation and adipocyte hypertrophy in obese mice (8-week-old C57BL/6 male mice) fed with commercial macadamia nut oil (Vital Atman, Uchoa, SP, Brazil) was also reported. Clinical and epidemiological studies using CPMO are needed to see if it has similar effects in humans.

APPLICATION OF COLD-PRESSED MACADAMIA NUT OIL

As shown in Table 4, various food and non-food applications for macadamia nut oil include food fortification, the development of skin, hair, and health care products. The effect of coating CPMO with macadamia protein isolate, and chitosan hydrochloride on microencapsulation efficiency and the properties of the spray-dried powders were studied The authors highlighted that macadamia protein isolate and chitosan hydrochloride mixed with CPMO at a ratio of 5:1 gave the highest encapsulation efficiency (94.2%) and the best oxidation stability (<4 meqO_2/kg oil), and good storage stability after rehydration. The authors concluded that converting CPMO into powder may enhance its application as a healthy lipid in food and non-food products.

The ability of CPMO to improve the oxidative stability of palm olein oil during deep-fat frying was also investigated. Palm olein oil was blended with 25–75% CPMO, and the oil blends were subjected to smoking and oxidative degradation.

TABLE 4. Food and non-food applications of cold-pressed macadamia nut oil

Product and Application	Technique Used	Amount of Macadamia Oil Used	Key Parameters Evaluated	Remark	Reference
Rehydrated emulsion: food fortification	Encapsulation and spray drying	8 g of macadamia oil	Encapsulation efficiency, hygroscopicity, wettability and solubility, bulk density and flowability, oxidative stability	Macadamia protein isolate and chitosan hydrochloride mixed with macadamia oil at a ratio of 5:1 gave higher encapsulation efficiency and stronger protection against lipid oxidation	Zhong *et al.*
Solid-lipid microparticles: drug delivery system for hydrophilic active ingredients with low permeability	Emulsification	40–55% macadamia and corn oil	Entrapment efficiency and retention rate, droplet size, viscosity, stability, skin penetration	The solid-lipid microparticles resulted in 5.52-fold increase in absorption of vitamin C.	Gu *et al.*
Palm olein oil and macadamia oil blend: stabilize vegetable oils during deep fat frying	Blending	25–75% macadamia oil	Smoke points and oxidative stability	Blended oils showed improved induction period and inhibited primary and secondary oxidation products formation.	Koohikamali and Alam
Esters and surfactants: emulsifiers in the development of hair and skin care products	Esterification	187–881g of macadamia oil	Skin feel, emolliency, slip, stickiness, moisturizing effect, viscosity, refractive index, spreading coefficient	The macadamia-based esters and surfactants showed good ease of emulsification, good refractive index, emolliency with good after-feel, lack of greasiness, low cloud point and pour point and high spreading coefficient.	Syed *et al.*
Lipstick: cosmetic for making up or caring for the lips	Blending and cooling	18.7% macadamia oil	Hardness, organoleptic tests	Good organoleptic properties and lip moisture maintenance	Blin and Guillard

It was established that the oil blends improved the induction period and inhibited primary and secondary oxidation products formation, a phenomenon that was attributed to the higher oxidative stability of MUFA and natural antioxidants present in macadamia nut oil. Besides applying CPMO in the formulation of oil blends with improved oxidative stability, the approach may be applied to formulate healthier and functional diets higher in oleic acid and palmitoleic acid. Although it was acknowledged that the price of oil blends could be higher, costs could be lowered by decreasing the number of frying oil replenishment during the frying cycles by taking advantage of the enhanced stability.

Fatty acid composition is crucial in developing cosmetic and skincare products. The literature reports that fatty acids similar to those found in the human body, such as palmitic acid, oleic acid, and linoleic acid, are crucial for the biological functions of the body. Palmitoleic acid, one of the predominant monounsaturated fatty acids in CPMO, forms part of the sebum of human skin. To this effect, the composition of CPMO makes it a desirable ingredient in the formulation of skincare and anti-aging creams.

One research group established that CPMO could be successfully applied in the production of esters and surfactants, which are valuable in the development of hair and skincare products. The authors reported that the CPMO-based esters and surfactants showed good ease of emulsification, good refractive index, emolliency with good after-feel, lack of greasiness, low cloud point, and pour point and high spreading coefficient characteristics desired in hair and skincare products. Moreover, macadamia nut oil easily penetrates, softens, and influences the condition and proper functioning of the skin. Solid-lipid microparticles with 40–55% CPMO and corn oil developed at laboratory scale enhanced the absorption of vitamin C by the skin. Therefore, CPMO based solid-liquid microparticles could be used as a drug delivery system for hydrophilic active ingredients with low permeability. A skincare product containing at least 25% CPMO was reported to contribute to the prevention or reduction of dryness, irritation, and skin lacerations in the elderly. Moreover, patented the use of CPMO in lipstick production has been patented, and the patent holders claimed that the oil assists in the maintenance of lip moisture.

Overall, the findings of this review may incite further studies on the health benefits and application of CPMO.

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Is now the time for microbial lipid production?

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

Rebecca Guenard

Saturated fats are rare in the plant kingdom. However, companies invested in producing plant- or cell-based alternatives to animal products, like meat, eggs, or dairy, need a fat replacement. To mimic the sensory qualities of the harder, saturated fats typically found in animal products, food scientists are eagerly searching for new sources.

A ballooning number of plant-based diet converts express that their motivation for changing their eating habits is the planet's health more than their own. A recent survey of Americans found that people under the age of 40 years (over 30% of the US population) responded with "taste" as their primary reason for making a plant-based purchase (https://tinyurl.com/2p83hr9w). After taste, this consumer group indicated their motivation for choosing plant-based was environmental sustainability. Now, the industry is scrambling to meet the demands of this younger generation.

"The entire food manufacturing system that we created is shifting toward the production of something that is more sustainable," says Alejandro Marangoni, food science professor at the University of Guelph in Ontario, Canada, and AOCS fellow. He says that consumers are not just focused on their energy consumption or carbon signatures anymore. They want to know that the raw materials used to produce their food are sustainably sourced.

Marangoni recently published a review article with his research associate and long-time AOCS member Saeed Ghazani, aimed at addressing the need for plant-based lipids. The paper, published in *Trends in Food Science and Technology*, evaluates the potential for producing lipids from microbial sources (https://doi.org/10.1016/j.tifs.2021.10.014). Plant-based foods have reached mainstream status; can food manufacturers parlay their popularity into the development of new lipid sources?

According to SPINS, a company in Chicago, Illinois, USA that collects retail data for investors in natural and organic food products, sales of plant-based food grew 2.5 times faster than total food sales between 2018 and 2020 (https://gfi.org/marketresearch/). By the end of 2020, the plant-based food market was worth $7 billion, up from $5.5 billion in 2019. Despite the interest consumers have shown toward these products, manufacturers worry they will not gain brand loyalty without plant-sourced fats that provide a similar mouth feel to animal fats.

"Looking for new fat sources for food production that fulfill sustainability, health, and economic requirements is a challenge," says Marangoni. His latest paper evaluates decades of research on oleaginous microorganisms and evaluates whether today's economics offer the opportunity to commercialize the lipids they produce.

Under specific conditions eukaryotes, such as yeast and fungi, convert carbon from sugars into fatty acids. According to the paper, some yeasts and microalgae can produce triacylglycerols (TAGs) at a rate of 70% of their dry biomass. Marangoni says he focused on TAG-producing microorganisms since TAG are commonly used in food production.

There are hundreds of yeast species and thousands of fungal species, but only a handful of these organisms accumulate enough lipids to make them economically interesting. When they are depleted of a nutrient, like nitrogen, during growth the microbes accumulate mostly TAGs and some sterol esters as energy reserves. The process happens quickly compared to agricultural time frames. Researchers report that a single fermenter can produce as much microbial oil in 4 days as 30 acres of crops can in a year (Table 1).

Since the 1980s, researchers have been investigating the optimal conditions for maximizing TAG production in oleag-

TABLE 1. A comparison of expected oil yields for various crops and yeast varieties. Source: Jones, A. D., *et al.*, New York: Humana Press, 2019.

Lipid Source	Oil content (% w/w)	Oil yield for the plant sources (kg/ha/year)	Oil yield for the yeast source (kg/m³/year)
Rapeseed	45	600–700	
Soybean	20	450–500	
Palm	50	3,000–5,000	
Sunflower	45	500–700	
Rhodosporidium toruloides	58-68		2,120
Cryptococcus curvatus	25–46		1,154
Lipomyces starkeyi	61–28		410

inous microorganisms. These conditions are specific to the individual species of an organism, but are generally moderate compared to typical manufacturing processes. Yeast requires relatively low temperatures, as well as low concentrations of nitrogen and oxygen to produce lipids in the range of 70% cell dry weight.

Microorganisms depend on a carbon-rich growth medium to acquire such high lipid values. The most common source for yeast growth is glucose. Feeding glucose to yeast provides one lipid for every five sugars the microbe eats. For oleaginous microorganisms to compete economically with agricultural lipids, one obstacle will be reducing the cost of growth medium.

Depending on the species, other carbon sources, such as agro-industrial waste or sewage sludge, can be used to produce lipids. Waste streams from a variety of other food industry manufacturing processes have also been investigated as possible carbon sources, but they all require physiochemical and enzymatic pretreatments that increase production costs.

Another barrier in the way of cost effective microbial lipid manufacturing is the process of extracting the oil from the cells. Microorganisms with cell walls sturdy enough to contain lipids are difficult to rupture. Once they finally burst the oil must be extracted from the aqueous medium where the organisms were grown. Further processing steps are needed to then remove impurities from the oil.

Marangoni points out that all these challenges provide an opportunity for scientists to discover creative solutions. For example, a research group in Uruguay averted rupturing the cells and extracting the oil by *in situ* transesterification (https://doi.org/10.1016/j.ejbt.2018.11.006). The researchers directly interesterified the lipids within the yeast cells simplifying further processing.

Working with the microorganism's genetics to optimize lipid production for ideal fatty acid ratios will also expand the production capabilities of microbial oils. Marangoni says, he would like to see the kind of success achieved with gene editing that led to high-oleic oils duplicated with a high-steric or other type of high-saturated plant oil. Gene editing experiments are usually significantly faster in a microorganism than an agricultural crop.

"In my career, this is the most exciting time that there has ever been to be in food research," says Marangoni. He says he is confident that manufacturers will eventually be able to make microbial lipids that behave the same as animal fats. Research conducted 40 years ago produced cocoa butter and palm oil equivalents from yeast. At the time, there was no economic driver to carve out a market share for these products.

The manufacturing expense has always hindered the success of commercializing microbial lipids. Until the price of these products can at least align with higher end fats, like shea butter, harvesting lipids from yeast will remain an academic fantasy. However, today's plant-based food trend, with its moral footing secured on the idea of sustainability, could provide the foundation needed to support a microbial oil movement.

With climate change and population growth, environmental conditions and land access are no longer assured which complicates traditional agriculture. Marangoni says as societies have to adapt microbial oils may offer the flexibility they will need to progress into future food production.

Rebecca Guenard is the associate editor of Inform *at AOCS. She can be contacted at rebecca.guenard@aocs.org.*

Information

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Process conditions for a rapid *in situ* transesterification for biodiesel production from oleaginous yeasts, Martinez-Silveira, A., R. Villarrea, and G. Garmendia, *et al.*, *Electron J. Biotechnol. 38*: 1–9, 2019.

Three quarters of inspected products sold online breach EU chemicals laws

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

Three out of four products sold online are non-compliant with at least one requirement under relevant EU chemicals legislation, enforcement authorities have found.

Inspectors in 29 countries checked 5,730 substances, mixtures and articles sold in online shops and marketplaces during the Echa enforcement forum's eighth REACH project (Ref-8). Products were checked for compliance with REACH, the classification, labelling and packaging (CLP) and the biocidal products (BPR) Regulations.

Seventy-eight percent of products checked for compliance with REACH restrictions were in breach of the law, according to the project results released on December 8, 2021.

Non-compliance was at 95% for restrictions on substances and mixtures, and 25% for restrictions in articles. The difference could come down to the difficulty in determining this for articles without chemical analyses, Echa said.

Results were particularly sobering for products containing carcinogenic, mutagenic, or reprotoxic substances (CMRs), such as lead in solders for welding needs and boric acid. These should be restricted to professional users but 99% were available for consumers to buy online.

Inspectors also checked safety data sheets where available online and in the language of the receiving member states. Here, non-compliance was at only 5%.

And 75% of products checked were non-compliant with the CLP Regulation, Echa reported. Most commonly, online shops and marketplaces did not provide the required information on chemical hazards in the online advertisement of the product.

However, the report noted that "in many member states, products/offers inspected were those for which risk was assumed to be high, and therefore those with highest risk were targeted (risk-based approach), which may have contributed to a higher-than-expected rate of non-compliance for most obligations examined in the project."

BIOCIDES

Inspectors found that 77% of inspected biocidal products were non-compliant with at least one requirement under the BPR.

At 79%, the highest rate of non-compliance was for repellents and attractants (product-type 19).

And results mirrored problems with misleading advertising. Seventeen percent of biocidal products featured statements such as "low-risk", "non-toxic", "harmless" or "environmentally friendly", which the BPR forbids.

Advertisements for 70% of the products checked were missing the obligatory sentences: "Use biocides safely. Always read the label and product information before use."

Echa also flagged a stark contrast between webshops, which own the product they sell, and online marketplaces, which act on behalf of other sellers as intermediates. The non-compliance rate was at 95% for marketplaces and 65% for webshops.

Following the inspections, national enforcement authorities initiated more than 5,000 enforcement measures. In most cases, companies were asked to remove the product offer from their websites or bring their advertisements into compliance.

RESPONSIBILITY

At four times higher the non-compliance rates normally found during spot checks in stores or by customs officials, the Ref-8 results show "a fundamental issue with compliance" for online sales, Maciej Baranski from Echa's harmonized enforcement team said.

"Considering the volume of online sales is only likely to grow, this problem is going to become more pressing in the future," he said. "Overall, I think we really need a shift in paradigm of how online sales are regulated in the EU."

Echa calls for more responsibility to be put on the actors behind the sale of goods online.

The Ref-8 report recommends the European Commission:

- make marketplaces more responsible and liable for enforcement of illegal products, particularly those from outside of the EU;

- harmonize and strengthen the regulation of online commerce in the EU; and
- support and finance EU enforcement.

Echa said marketplaces are in a position to proactively seek out non-compliance in products sold on their platforms, via automated tools, spot checks or occasional chemical analyses of products.

Meanwhile, the agency is asking industry bodies to help raise awareness of the requirements under chemicals legislation.

Echa's enforcement forum is geared up to organize a stakeholder workshop "in the first half of next year" to discuss the Ref-8 findings and the agency's recommendations.

A STARK REMINDER

Consumer rights NGO Beuc echoed Echa's call to action. "We are convinced that marketplaces must stop burying their heads in the sand and become liable for what they sell," said Sylvia Maurer, director of sustainability and safety at Beuc.

"It is sadly nothing new that online platforms abound with unsafe products such as clothes, toys, or childcare articles. Consumer groups from across the EU flag unwanted chemicals in everyday products year in, year out.

"Today's sweep by Echa is a stark reminder that a lot needs to be done, and must be done now," she said.

Cefic agreed the results are "no surprise" and confirm the need to double down on enforcement under the EU's chemicals strategy for sustainability. The trade body called for "a clear plan and support" from the Commission to implement the recommendations, recently outlined in the report of the strategy high-level roundtable.

"One of the key issues is that today, online platforms do not have clear responsibilities and obligations in EU chemicals legislation. To help tackle the issue, we need to ensure that online platforms have explicitly defined roles in the supply chain and that they comply with EU laws on chemicals and products," Cefic said.

"Overall to tackle imports, whether offline or online, we need coordinated and harmonized enforcement across the member states. We support a stronger role for Echa's enforcement forum, which is a unique platform to coordinate enforcement priorities and actions across the member states."

Meet Uwe Bornscheuer

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

Uwe Bornscheuer on his sailboat Luna near Greifswald on the Baltic Sea. He is using the equivalent of a selfie stick to manipulate the tiller more comfortably.

Fast facts

Name	Uwe Bornscheuer
Joined AOCS	1998
Education	PhD in chemistry, University of Hannover (Hannover, Germany)
Job title	Professor and head of the Department of Biotechnology & Enzyme Catalysis at the Institute of Biochemistry
Employer	University of Greifswald (Greifswald, Germany)
Current AOCS role	Associate editor (since 1998) of the *Journal of the American Oil Chemists' Society*

PROFESSIONAL

What's a typical day like for you?
Waking up, having a coffee, reading the (printed!) newspaper during breakfast. Usually, I have a relaxing walk to the Institute (it is quite close to my home) and this helps me to get started. The rest of the day is full with online meetings and computer work, but luckily also with in-person discussions with my group members.

My favorite part of my job is…
Getting young students interested in my research field and seeing them growing over the years to become highly motivated, creative, and dedicated researchers.

Flash back to when you were 10 years old. What did you want to be when you grew up?
I discovered my interest in chemistry early in high school, with the side effect that most likely toxic fumes were created in the cellar of my parents' house while I made my first experiments.

Why did you decide to do the work you are doing now?
I almost became a journalist after high school, but then I had the option to study chemistry in Hannover. Over the years, I found biochemistry, and especially working with enzymes, more interesting, so I then learned microbiology, molecular biology, and computer-modeling methods.

Is there an achievement or contribution you are most proud of? Why?
Every five years, I invite former PhD students and postdocs to celebrate in Greifswald. I am proud that so many previous group members make the trip to this remote city for the reunion.

What event, person, or life experience has had the most influence on the direction of your life?
Although several individuals have influenced my career steps, I am especially grateful to Mike Haas (formerly at USDA, and a past president of AOCS) for promoting my interest in the field of fats, oils, and lipids.

PERSONAL

How do you relax after a hard day of work?
Preferably sailing or having a motorbike tour, otherwise reading a book, listening to my favorite music, meeting with friends, or spending time with my wife and daughter.

What is the most impressive thing you know how to do?
Probably setting and steering the Spinnaker—a special type of sail—under tough conditions during a sailing regatta. This requires full attention all the time to keep the sail stable, as well as close interaction with the team on board. It's a bit like running a challenging research project, now that I think about it.

What is a small thing that makes your day better?
Learning that one of our publications has been accepted. Even after more than 500 publications, I still suffer along with my PhD students over the peer-review process. (There is always one difficult reviewer.)

PATENTS

Lipid powder composition comprising a salt mixture

Cruz, S., Team Foods Colombia S.A., US11033046, June 15, 2021

The present invention, in an embodiment, is a powder composition that includes 20 to 80 weight % of a triglycerides mixture and 15 to 75 weight % of a salt mixture. The triglyceride mixture, based on a total fatty acid content of the triglycerides mixture, includes: 5% to 55% lauric acid content, 2% to 30% myristic acid content, 6% to 45% palmitic acid content, and 2% to 25% stearic acid content; 15% to 45% oleic acid content, 15% or less linoleic acid content, 10% or less linolenic acid content; and less than 2% of trans fatty acids; wherein, the salt mixture includes at least 90 weight % sodium chloride, based on the total weight of the salt mixture and a remainder includes at least one of sodium citrate, disodium citrate, monosodium tartrate, or disodium tartrate.

Plant based emollient

Barker, W.E., self, US11033595, June 15, 2021

The disclosure relates to a plant based emollient composition. The composition includes palm kernel oil and an aloe vera plant extract. The composition is useful alone or as a vehicle for small quantities of herbs, vitamins, medications, minerals, vinegars, essential oils (as examples) added during the composition's liquid phase.

Antioxidant, anti-inflammatory compositions and uses thereof

Sambanthamurthi, R., *et al.*, Malaysian Palm Oil Board, June 15, 2021

Compositions comprising oil palm phenolics and shikimic acid or derivatives thereof and their use in enhancing anti-oxidative and anti-inflammatory properties.

Lipid derivative for nucleic acid introduction

Asai, T., *et al.*, Nippon Fine Chemical Co., Ltd. and Shizuoka Prefectural University Corp., US11034708, June 15, 2021

An object is to provide a lipid particle that is not positively charged at a pH of the body fluid (typically in the neutral range), and that enables efficient onset of the effect of a medicinal substance encapsulated in the lipid particle; and to provide a lipid for forming the lipid particle. The object is achieved by the phospholipid represented by formula (1), and a lipid particle containing the phospholipid: ##STR00001## wherein R.sup.1 and R.sup.2 are identical or different, and represent a chain hydrocarbon group, m represents 1 or 2, n represents 1 or 2, and p represents an integer of 1 to 4.

Method for obtaining bloom-retarding components for confectionary products

Juul, B., AAK Denmark A/S, US11039627, June 22, 2021

The invention relates to a method for producing a bloom-retarding component for chocolate and chocolate-like products, the method comprising the step of: Deodorizing a triglyceride composition, said triglyceride composition comprising at least 40% by weight of mono unsaturated symmetric triglycerides selected from the group consisting of POP, StOSt and POSt, where P equals palmityl, St equals stearyl and O equals oleyl, the deodorizing taking place for at least 60 minutes at a temperature of at least 220°C.

Hydrophobic gel based on vitamin e free from silicone products for topical application

Panin, G., BIO.LO.GA. S.R.L., US11039991, June 22, 2021

A hydrophobic gel formulation for topical use, free of silicone products, comprising in weight percentage on the total weight of the formulation: from 10 to 50% of vitamin E, from 20 to 60% of a vegetable butter or a wax, from 10 to 30% triglyceride of caprylic and capric acid and from 3 to 10% of a gelling agent for lipids such as the triglyceride of palmitic and stearic acid.

Compositions with natural oils for providing a protective barrier

Maron, Z., *et al.*, L'Oreal, US11039993, June 22, 2021

A composition provides a protective barrier and includes glyceryl dibehenate, tribehenin, and glyceryl behenate, a surfactant that includes glyceryl stearate, hydrogenated vegetable oil, one or more additional fatty compounds, and one or more triglyceride. The composition optionally includes wax, a hydrating agent, and may be essentially free of or is devoid of one or more of petrolatum, mineral oil and water. The composition provides occlusivity and hydration effects that are comparable to compositions that include one or more of petrolatum, mineral oil and lanolin.

Composition suitable for cleansing

Ichinokawa, T., L'Oreal, US11039998, June 22, 2021

A composition contains (a) at least one fatty acid sugar ester; (b) at least one anionic surfactant selected from amino acid surfactants and taurate surfactants; (c) at least one polyoxyalkylenated polyol fatty acid ester having an HLB value of 12 or less; (d) at least one oil; (e) at least one polyol; and (f) water. An embodiment according to the present invention can be stable before being applied onto the skin and provides quick texture transformation after being applied onto the skin, and therefore, is useful as a cleansing product.

Super-hydrophilic/underwater super-oleophobic separation membrane and preparation method thereof

Zhou, S., *et al.*, Huaiyin Normal University, US11040313, June 22, 2021

The invention is related to a super-hydrophilic/underwater super-oleophobic attapulgite separation membrane, and a preparation method and use thereof. Monodispersed hydrophilic nanoparticulates are loaded on a surface of nanoparticles, to obtain a super-hydrophilic nanocomposite material with a micro-nano-structure. The nanocomposite material is dispersed in a mixed aqueous solution of polyacrylamide and methyl cellulose, to obtain a membrane-forming slurry after vigorous stirring. A disc-shaped porous support is infiltrated with water and placed on a horizontal surface, and then a certain volume of the membrane-forming slurry is slowly and uniformly drip-coated on a surface of the support, dried and sintered to obtain a super-hydrophilic/underwater super-oleophobic microfiltration membrane layer.

Phospholipid dedusting agents for joint compounds

Donovan, A.J., United States Gypsum Co., US11040910, June 22, 2021

A drying-type joint compound, a setting-type joint compound, and/or a ready-mixed, setting-type joint compound can include a phospholipid dedusting agent. For example, a drying-type joint compound can include: (a) a primary filler at 50 weight percent (wt %) to 98 wt % on a dry basis, wherein the primary filler includes one of calcium carbonate, calcium sulfate dihydrate, and talc, and a mixture thereof (b) a secondary filler at up to 25 wt % on a dry basis; (c) a binder at 1 wt % to 15 wt % on a dry basis; (d) a polymer thickener at 0.05 wt % to 3 wt % on a dry basis; (e) a phospholipid dedusting agent at 0.01 wt % to 3 wt % on a dry basis; (f) an additive up to 10 wt % o on a dry basis; and (g) water at a weight ratio of water to dry components of 1:6 to 2:1.

Anhydrous 2-pyridinol-n-oxide deodorant and antiperspirant compositions.

Sturgis, D.A., *et al.*, The Procter & Gamble Co., US11045408, June 29, 2021

A deodorant stick having a substituted or unsubstituted 2-pyridinol-N-oxide material and at least one material selected from the group consisting of hexamidine, magnesium carbonate, zinc carbonate, thymol, magnesium hydroxide, dead sea salt, calcium carbonate, polyvinyl formate, salycilic acid, niacinamide, and combinations thereof.

Method and composition for a stable oil-in-water emulsion for aesthetic improvement of food and beverage containers

Chaudhari, K., *et al.*, Diversey, Inc., US11046868, June 29, 2021

A coating composition for use in recycled beverage containers is disclosed. An emulsification of oil, fatty acids, a sorbitan ester and an alkoxylated alcohol is disclosed. Methods directed to using the coating composition are also disclosed.

Omega-3 fatty acid ester compositions

Sancilio, F., *et al.*, Micelle BioPharma, Inc., US11046909, June 29, 2021

Compositions including at least one omega-3 fatty acid ester and at least one surface active agent are provided; wherein the compositions form micelles when in contact with an aqueous medium. Also provided is a method of administering to a subject such a composition, wherein the at least one omega-3 fatty acid ester forms micelles when in contact with an aqueous medium, and the bioavailability of the at least one omega-3 fatty acid ester is substantially independent of a food effect. The compositions are useful for treating cardiovascular conditions or disorders in a subject and for reducing side effects associated with the ingestion of omega-3 fatty acid esters. Further provided are also various dosage forms for administering the compositions and use of the compositions in functional foods. Provided herein are also kits with instructions on how to administer the compositions.

Production of omega 3 long-chain polyunsaturated fatty acids in oilseed crops by a thraustochytrid PUFA synthase

Walsh, T.A., *et al.*, Dow AgroSciences LLC and DSM IP Assets B.V., US11046968, June 29, 2021

This disclosure concerns recombinant host organisms genetically modified with a polyunsaturated fatty acid (PUFA) synthase system and one or more accessory proteins that allow for and/or improve the production of PUFAs in the host organism. The disclosure also concerns methods of making and using such organisms as well as products obtained from such organisms.

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.

Single-blind vs. double-blind peer review

Peer review of academic research is at the heart of publishing. It is important that this process is not tainted by reviewer bias. Two popular modes of review exist. In single-blind peer review, the authors do not know who the reviewers are. The reviewers know who the authors are. In double-blind peer review, neither authors nor reviewers know each other's names. Single-blind peer review is the traditional model. However, both models exist to eliminate bias in peer review.

THE PHYSICS EXPERIMENT

At the start of 2017, the Institute of Physics (IOP) gave authors the option to choose double-blind peer review. This option was available for *Materials Research Express* and *Biomedical Physics & Engineering Express*. Over the first seven months, 20% of authors chose the double-blind peer review option. Authors from India, Africa, and the Middle East were most likely to request the option.

IOP data indicates that more papers received rejections under the double-blind model. About 70% of papers received a rejection in the double-blind peer review process. On the other hand, only 50% of papers received rejection under single-blind peer review. The difference could be due to reviewers assuming that authors requesting this option had written poor papers. It could also be due to reviewers acting more objectively. However, authors in the double-blind trial were satisfied and felt it was the fairest approach.

Bias in peer review is a real problem. There have been many studies showing that women and minorities are less likely to get published, funded, or promoted. This bias can be both conscious and unconscious. Within scientific publishing, this means that fewer women are asked to review papers. It also means papers by women are cited less. There are two peer review models where identities are hidden. Which is more likely to get rid of bias?

WHAT IS SINGLE-BLIND AND DOUBLE-BLIND PEER REVIEW?

Single-blind peer review is a conventional method of peer review where the authors do not know who the reviewers are. However, the reviewers know who the authors are. Whereas, double-blind peer review, is when neither authors nor reviewers know each other's name or affiliations.

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EXTRACTS & DISTILLATES

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

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

Review Articles

EAT Interactions between nanoparticle-based food additives and other food ingredients: a review of current knowledge

Moradi, M., *et al.*, *Trends Food Sci. Technol. 125*: 75–87, 2022, https://doi.org/10.1016/j.tifs.2022.01.012.

Nanomaterials are being explored in the food and agricultural industries for their potential applications in improving the safety, quality, health, and sustainability of the food supply. Numerous kinds of food-grade substances have been converted into nanoenabled food additives (such as colorants, flavors, antimicrobials, vitamins, and nutraceuticals) or advanced packaging materials (such as smart or active coatings/films). For these applications, it is important to understand how nanomaterials interact with other components in foods. Moreover, it is important to ensure that they do not have any unintended adverse health consequences, which also depends on an appreciation of their interactions with other food ingredients. In particular, nanomaterials can undergo various transformations in their properties in food matrices and the human gut that can alter their properties and behavior. The aggregation state, interfacial composition, and electrical charge of nanoparticles may change when they interact with macronutrients or micronutrients in foods, which may then alter their gastrointestinal fate. This article reviews the interactions of food-grade nanomaterials (especially inorganic ones) with proteins, carbohydrates, lipids, minerals, and phytochemicals in foods and their potential impacts on their functionality and behavior.

EAT Application of essential oils in meat packaging: a systemic review of recent literature

Smaoui, S., *et al.*, *J. Food Control 132*: 108566, 2022, https://doi.org/10.1016/j.foodcont.2021.108566.

The meat industry has designed biopolymer-based materials containing biomolecules as active packaging to diminish losses and improve the shelf-life of these products. This review examines the loading of essential oils in the active films and coatings, their impact on the chemico–physio–mechanico properties and antioxidant and antibacterial potential of numerous biopolymer films for packaging meat and derived products, their potential use when incorporated into biopolymer network matrices of these films. The biological effects of different types of edible films and nfluence of such functional packaging on improving meat product quality is also discussed. Interestingly, active films containing essential oil present a future approach and an environmentally friendly solution in the meat industry. In general, active food packaging was revealed to be a suitable technology to improve meat quality and reduce waste in the food industry.

EAT Recent trends and developments on integrated biochemical conversion process for valorization of dairy waste to value added bioproducts: a review

Awasthi, M.K., *et al.*, *Bioresour. Technol. 344*: 126193, 2022, https://doi.org/10.1016/j.biortech.2021.126193.

This article reviews the many ways utilized by the dairy sector to treat pollutants, emphasizing their influence on the quality and efficiency with which contamination is removed. It particularly focuses on biotechnology possibilities for valorizing dairy waste. The findings revealed that dairy waste may be treated using physicochemical, biological, and biotechnological techniques. Notably, this article highlights the possibility of dairy waste being used as a feedstock not only for the generation of biogas, bioethanol, biohydrogen, microbial fuel cells, lactic acid, and fumaric acid via microbial technology, but also for production of biooil and biochar by pyrolysis. In addition, this article critically evaluates the many treatment techniques available for recovering energy and materials from dairy waste, their combinations, and implementation prospects. Valorization of dairy waste streams presents an opportunity to extend the dairy industry's presence in the fermented functional beverage sector.

IOP PCP PRO BIO Production of biosurfactants from agro-industrial waste and waste cooking oil in a circular bioeconomy: an overview

Gaur, V.K., *et al.*, *Bioresour. Technol. 343*: 126059, 2022, https://doi.org/10.1016/j.biortech.2021.126059.

This article reviews looks at the production of biosurfactants from waste streams, such as agro-industrial waste and waste cooking oil. The need for waste stream-derived circular bioeconomy and scale-up of biosurfactant production are punctuated with examples of biosurfactant applications in environment and industrial sectors. Roadblocks and future directions for research are also discussed.

Original Articles

EAT BIO Glycerolysis structured oils as natural fat replacements

Nicholson. R.A. and A.G. Marangoni, *Curr. Opin. Food Sci. 43*: 1–6, 2022, https://doi.org/10.1016/j.cofs.2021.09.002.

Lipase-catalyzed glycerolysis can effectively structure a variety of plant-based oils into solid fats without altering fatty acid compositions. The physical properties of glycerolysis-structured systems changed with oil fatty acid composition, producing solid fat content (SFC)-temperature profiles suitable for different applications. High oleic oils containing >10% saturated fat showed the greatest SFC increases. SFCs of tigernut and olive oils at 5°C increased from 8%– 34% and from 0%–24%, respectively, following glycerolysis. Glycerolysis-structured tigernut oil has been used to make margarine of similar plasticity and firmness to commercial margarine and butter with preferable melting properties. The ability to further tailor physical properties of oils using the glycerolysis reaction makes this an appealing process for producing natural fat replacements.

EAT LOQ Evaluation of an innovative sheep cheese with antioxidant activity enriched with different thyme essential oil lecithin liposomes

Gil, K.A., *et al.*, *LWT–Food Sci. Technol. 154*: 112808, 2022, https://doi.org/10.1016/j.lwt.2021.112808.

The aim of this study was to develop an innovative sheep cheese enriched with *Thymus capitatus* L. essential oil (EO) nano-incorporated into small homogeneous liposomes. The latter were prepared using two types of lecithin: one commonly used for liposome production, and the other used as dietary supplement. Both EO liposomes, which showed similar physico-chemical characteristics (i.e., size, homogeneity, surface charge), were incorporated into fresh sheep cheese. These enriched sheep cheeses were produced in Sardinia (Italy) and analyzed 20, 60, and 180 days after preparation. HS-SPME at 40 and 80°C coupled with GC-MS/FID method was used to evaluate the volatile fraction and identify the main compounds of both EO and cheese. A validated HPLC-DAD analysis allowed the identification and quantification of thymol and carvacrol, and thymol amount dosed at 20 days was the highest (9.51–10.10 mg/kg). The amount of monoterpenoid phenols and the antiradical and total antioxidant capacity evaluated by FRAP and DPPH• assays, decreased linearly ($r \geq 0.93$, $p \leq 0.05$) as the cheese maturation increased. Overall results suggested that sheep cheese enriched with *T. capitatus* EO nanoformulations had an enhanced antioxidant activity compared to cheese without liposomal EO, up to 180 days.

EAT LOQ Active packaging films containing antioxidant extracts from green coffee oil by-products to prevent lipid oxidation

Vidal, O.L., *et al.*, *J. Food Eng. 312*: 110744, 2022, https://doi.org/10.1016/j.jfoodeng.2021.110744.

The residual biomass of cold-pressed green coffee oil (GCO), rich in chlorogenic acids (CGA), was reused by incorporating the press cake (CE) and sediment (SE) extracts into carboxymethyl cellulose (CMC) films. The effect of these extracts combined with GCO was investigated on the physicochemical, barrier, and antioxidant properties, and on the ability of the active films to delay fish oil oxidation. The films with added CE and GCO (C-CE) or SE and GCO (C-SE) showed high antioxidant activity, 3.61 ± 0.01 and 2.03 ± 0.01 mmol Trolox eq/g dry film, respectively. These findings are in line with the CGA content in CE and SE (9.8 and 9.0% w/w, respectively), as determined by HPLC. The addition of SE and GCO slightly affects the oxygen barrier of CMC films, while providing them with high Ultraviolet–Visible (UV–Vis) absorption. The evolution of peroxide value (PV) and thiobarbituric acid reactive substances (TBARS) in fish oil samples covered by C-CE and C-SE films and inert headspace was significantly lower than those of controls (storage at 40°C for 16 days). The antioxidant release from films with added CE and SE showed an antagonistic behavior into the food simulants. Although both active films are promising for active packaging, the C-SE film appeared as more advantageous for oil-rich food protection.

EAT IOP Synthetic fat from petroleum as a resilient food for global catastrophes: preliminary techno-economic assessment and technology roadmap

García Martínez, J.B., *et al.*, *J. Chem. Eng. Res. Design 177*: 255–272, 2022, https://doi.org/10.1016/j.cherd.2021.10.017.

Human civilization's food production system is unprepared for global catastrophic risks (GCRs), catastrophes capable of abruptly transforming global climate such as supervolcanic eruption, aster-

oid/comet impact, or nuclear winter, which could completely collapse the agricultural system. Responding by producing resilient foods requiring little to no sunlight is more cost effective than increasing food stockpiles, given the long duration of these scenarios (6–10 years). This preliminary techno-economic assessment uncovers significant potential for synthetic fat from petroleum as a resilient food source in the case of an abrupt sunlight reduction catastrophe, the most severe food shock scenario. To this end, the following are roughly quantified based on literature data: global production potential, capital and operating expenditures, material and energy requirements, ramp-up rates, and retail prices. Potential resource bottlenecks are reviewed. Synthetic fat production capacity would be slower to ramp up compared to low-tech food production alternatives, but provides the fat macronutrient, largely absent from these. Using 24/7 construction of facilities, 16–100% of global fat requirements could be fulfilled at the end of the first year, potentially taking up to 2 years to fully meet the requirements. Significant uncertainty remains on several topics including production potential, capital expenditure, food safety, transferability of labor, and equipment construction. A technology roadmap is proposed to address these concerns and develop the potential of synthetic fat as a catastrophe-resilient food.

IOP PCP BIO Influence of bioprocess parameters on sophorolipid production from bakery waste oil

To, M.H., *et al.*, *Chem. Eng. J. 429*: 132246, 2022, https://doi.org/10.1016/j.cej.2021.132246.

Secondary/waste streams have previously been used as feedstocks to produce sophorolipids (SLs), biosurfactants with low eco-toxicity and high biodegradability, to reduce production costs and protect the environment. However, limited productivities and titres from these feedstocks remain important challenges. Thus, the optimization of fermentation medium using bakery waste oil (BWO) as a hydrophobic carbon source by *Starmerella bombicola* was investigated. The optimal conditions were determined by multiple linear regression. Inoculum concentration of 2% v v^{-1} and BWO and glucose concentrations of 60 g L^{-1} and 100 g L^{-1}, respectively, resulted in an increase of 19.6% in the lactonic SL (67.8 ± 11.5 g L^{-1}). Further optimization revealed the profound influence of KOH in pH regulation, i.e., compared with NaOH, KOH led to higher concentrations of biomass ($p < 0.05$), more BWO consumption, and thus, an increase of 42.2% in SL titre (96.4 ± 9.1 g L^{-1}) and corresponding volumetric and specific productivities of 0.446 g $L^{-1}h^{-1}$ and 0.027 g g $CDW^{-1}h^{-1}$, respectively. Multiple regression analysis demonstrated that pH and the concentration of BWO as the feeding medium were the most influential parameters in fermentative SL production. This study demonstrated that KOH offered additional benefit to improve SLs titre by maintaining high biomass during the bioprocess, displayed the importance of intracellular potassium in cell viability and improved the valorization of BWO process.

LOQ H&N Identification of novel antihypertensive peptides from wine lees hydrolysate

Bravo, F.I., *et al.*, *Food Chem. 366*: 130690, 2022, https://doi.org/10.1016/j.foodchem.2021.130690.

Enzymatic-assisted extraction using Flavourzyme® has been demonstrated to be a useful methodology to obtain wine lees (WL) enriched in phenolic compounds and with enhanced antihypertensive activity. Nevertheless, taking into account that Flavourzyme® possess proteolytic activity, the release of bioactive peptides should not be ruled out. In this study, we investigate the presence of antihypertensive peptides in the WL hydrolysate. Peptides were separated into fractions by ultrafiltration and RP-HPLC. Next, peptide identification by nano-HPLC-(Orbitrap) MS/MS was performed in the fractions showing the highest angiotensin-converting enzyme inhibitory (ACEi) activities. Six peptides were identified; three of them showing ACEi (IC50) values lower than 20 μM. The peptide antihypertensive effect was evaluated in spontaneously hypertensive rats at an oral dose of 10 mg/kg bw. Peptides FKTTDQQTRTTVA, NPKLVTIV, TVTNPARIA, LDSPSEGRAPG and LDSPSEGRAPGAD exhibited antihypertensive activity, confirming that they could contribute to the blood pressure-lowering effect of the WL hydrolysate. These peptides have a great potential as functional ingredients to manage hypertension.

LOQ H&N Enhancing the nutritional and functional properties of *Pleurotus citrinopileatus* mushrooms through the exploitation of winery and olive mill wastes

Koutrotsios, G., *et al.*, *Food Chem. 370*: 131022, 2022, https://doi.org/10.1016/j.foodchem.2021.131022.

Treatment and disposal of wineries and olive-oil mills waste is usually associated with complex processes, which are often of limited wide-scale applicability. Olive-leaves plus two-phase olive mill waste (OLW) or grape marc plus wheat straw (GMW) were assessed as substrates for the cultivation of the choice edible mushroom *Pleurotus citrinopileatus*. GMW led to increased mushroom biological efficiency and shorter production cycles. Antioxidant activities, triterpenic acids, free amino acids, lovastatin, and ergosterol were significantly higher in fruitbodies from GMW; the latter compound was positively correlated with squalene concentrations in substrates. Glucans, resveratrol, and fatty acid contents showed minor differences among mushrooms from the three substrates examined, whereas ergothioneine was significantly higher in fruitbodies grown on OLW. High correlations were noted for oleanolic, ursolic, and amino acid content in mushrooms and their respective substrates. Moreover, FTIR spectra revealed variations in fruitbodies content in bioactive compounds which were associated with the substrates used.

PRO IOP Techno-economic analysis and life-cycle analysis of renewable diesel fuels produced with waste feedstocks

Ou, L., *et al.*, *ACS Sustain. Chem. Eng. 10*: 382–393, 2022, https://doi.org/10.1021/acssuschemeng.1c06561.

Wet waste feedstocks represent an important category of resources that could be used to produce biofuels. Diverting wet waste resources from conventional waste management to feedstocks for energy production also eliminates the costs and pollutant emissions associated with waste management and disposal. This study investigates the economic and environmental implications of producing bio-blend stocks for mixing controlled compression ignition engines from two waste-to-fuel pathways: hydroprocessed esters and fatty acids (HEFA) from yellow grease and swine manure hydrothermal liquefaction (HTL) followed by biocrude upgrading. Detailed process models were developed for both pathways, which informed the techno-economic analysis and life-cycle analysis. Conventional swine manure management was also modeled in detail as the business-as-usual scenario for the swine manure HTL pathway. The estimated minimum fuel selling prices were \$1.22/gasoline liter equivalent (GLE) and \$0.94/GLE for the yellow grease to HEFA and swine manure HTL pathways, respectively. The life-cycle greenhouse gas (GHG) emissions of the two pathways were 11.2 and –33.3 g of CO_2e/MJ, respectively, for the yellow grease to HEFA and swine manure HTL pathways. The credits of avoided emissions from conventional swine manure management were the main reason for the negative GHG emissions of the swine manure HTL pathway. The marginal GHG emissions abatement costs were estimated to be \$116–\$270/metric ton (MT) CO_2e and \$5–\$103/MT CO_2e for the yellow grease HEFA and swine manure HTL pathways, respectively, for a diesel price ranging between \$0.5/GLE and \$0.9/GLE. Since the yellow grease HEFA pathway is already commercialized, it can benefit from the \$200/MT carbon credit in the California Low Carbon Fuel Standard market, which could help the yellow grease HEFA pathway to achieve near-zero marginal GHG emissions abatement cost.

PRO IOP Modeling and simulation of a multi-bed industrial reactor for renewable diesel hydroprocessing

Tirado, A., *et al.*, *186*: 173–182, March 2022, https://doi.org/10.1016/j.renene.2021.12.143.

The complexity of designing and optimizing vegetable oil hydrotreating reactors lies in describing multiple phenomena, including heat and mass transfer, hydrogen consumption, pressure drop, and a complicated network of highly exothermic reactions. This study analyzes the behavior of a vegetable oil hydroprocessing unit in a commercial environment via modeling and simulation techniques. To describe the three-phase (gas-liquid-solid) system in a detailed manner, a commercial-scale reactor model having multiple catalyst beds and inter-bed quench gas injections was constructed to account for the heat and mass transfer between phases, the dynamic response of the system, the variation in gas phase velocity, and intraparticle effects. Based on dynamic reactor simulations, quench gas injection strategies were proposed to control the reactor temperature profile and yield of the desired products. Simulation results showed that the selection of a feed inlet temperature plays a major role in reactor overheating, and quench injections must start as soon as the reactant stream reaches the inter-bed quench zone to stabilize reactor temperature more rapidly during start-up. In addition, the lengths of the catalyst beds need to be adjusted so the heat released by chemical reactions is properly distributed along the reactor. The results overall provide useful information for the design and optimization of commercial-scale catalyst bed configurations for hydrotreating renewable feedstock. In particular, it highlights that reactor temperature can be adequately controlled by means of an appropriate gas quenching configuration, allowing higher yields of green diesel.

PRO PCP Strategy for high-yield astaxanthin recovery directly from wet *Haematococcus pluvialis* without pretreatment

Myint, A.A., *et al.*, *Bioresour. Technol. 346*: 126616, 2022, https://doi.org/10.1016/j.biortech.2021.126616.

A novel integrated extraction technique for high recovery of natural astaxanthin from wet encysted *Haematococcus pluvialis* (*H. pluvialis*) is demonstrated. The technique can be used to effectively disrupt the cell wall and perform extraction in a one-pot system without a high-energy, cost intensive pre-drying step. The most suitable green solvent was researched in terms of high extraction yield and astaxanthin recovery. Moreover, an optimized condition for the selected green solvents was determined by varying process parameters, viz., the ball milling speed (100–300 rpm) and time (5–30 min). A high recovery of astaxanthin directly from wet *H. pluvialis* (30.6 mg/g based on its dry mass) and a high extraction yield (58.2 wt%) were achieved using ethyl acetate at 200 rpm after 30 min. Therefore, compared to its counterparts, the biphasic solvent system plays a key role in achieving high extraction yield and astaxanthin recovery from wet *H. pluvialis*.

PRO IOP Critical assessment of the filamentous green microalga *Oedocladium carolinianum* for astaxanthin and oil production

Wang, Y., *et al.*, *Algal Res. 61*: 102599, 2022, https://doi.org/10.1016/j.algal.2021.102599.

A filamentous microalga *Oedocladium carolinianum* isolated from soil was found to be capable of producing large amounts of astaxanthin under stress culture conditions. When the culture conditions were optimized, a maximum specific growth rate of 0.37 d^{-1} and maximum biomass concentration of 10.12 g L^{-1} were obtained after 18 days of cultivation in 1-liter glass columns (inner diameter: 5 cm) under laboratory conditions. However, when subjected to culture conditions of nitrogen starvation and 2 g L^{-1} NaCl-induced salinity stress, the cells produced up to 3.91% *w*/w astaxanthin and a high astaxanthin productivity of 24.2 mg L^{-1} d^{-1} was obtained. Analysis by HPLC-MS revealed that the majority of astaxanthin was in fatty acid esterified forms with a typical molecular ratio of free, monoester, and diester astaxanthin of 1:18:81. The biosynthesis of astaxanthin coincided with that of fatty acids, and the total fatty acid content reached 40% *w*/w or more. The technical feasibility of mass culture of *O. carolinianum* was tested in a 7,000-L inclined thin-layer photobioreactor and a 10,000-L tubular photobioreactor in a greenhouse. This demonstrated that *O. carolinianum* grew rapidly in a nitrogen replete BG-11 culture medium and the maximum biomass concentrations obtained in the inclined thin-layer photobioreactor and tubular photobioreactor were 3.74 g L^{-1} and 3.07 g L^{-1} respectively, resulting in maximum biomass productivities of 276 mg L^{-1} d^{-1} and 198 mg L^{-1} d^{-1}, respectively. Although small populations of a few zooplankton species occurred in the two types of photobioreactors, none grazed on *O. carolinianum* and they grazed on invading unicellular microalgae instead. It was therefore concluded that *O. carolinianum* is a promising microalga for sustainable co-production of astaxanthin and fatty acids.

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DOUBLE-BLIND VS. SINGLE-BLIND PEER REVIEW

The 2017 Web Search and Data Mining conference provided a good opportunity to experiment this theory. In Computer Science, papers often appear first (or exclusively) in peer-reviewed conferences. The program committee decided to randomly split its reviewers into two groups. One would serve as double-blind peer reviewers. The other as single-blind peer reviewers. The experiment would help decide which approach might have more bias.

The authors found that there were differences between the review groups. All reviewers had access to paper titles and abstracts. Based on this, reviewers indicated which papers they wanted to review. The single-blind reviewers requested to review 22% fewer papers. Single-blind reviewers were also more likely to choose papers from top universities or IT companies to review. They were also more likely to give a positive review to papers with a famous author.

Single-blind reviewers have access to the authors' names and institutions. The study indicates that author institution had a significant influence on single-blind reviewers' decisions to bid for a paper. There was no detected bias against female authors for this conference. A metareview combining this conference's data with other studies indicated that there was a significant bias against female authors.

The Web Search and Data Mining conference experiment show that single-blind reviewers use information about authors and institutions in their reviews. It could be that this information is helping the reviewers make better judgments. It could also be that this is putting work from non-prestigious institutions and authors at a disadvantage. Two papers of equal value may be rated differently by single-blind reviewers based on who wrote the paper.

A REVIEW OF PEER REVIEW

On the other hand, double-blind peer review provides a false sense of security. Well-known authors can be easily identified by the nature of their work. The paper may also make reference to previous work that they published. There may be other clues as well, such as a preference for a technique or compound. This means that, even without the names, reviewers can figure out who wrote a paper. It would, therefore, be better to tell the reviewer who wrote the paper and ask if there is a conflict of interest.

The actual process of removing author information to hide identity fails 46-73% of the time. The problem isn't identifying the author. The problem is whether reviewers have a prejudice against authors from a certain country, race, or gender? While the focus has mainly been on reviewers, very little discussion exists about biases of editors. Editors, after all, have the final say.

Peer review is part of the academic research cycle, and it is clear that there is bias in this process. Reviewer bias often affects women, minorities, and researchers from non-prestigious institutions. To try and fight this problem, journals use blind peer review. However, single-blind peer review gives the advantage to well-known authors. Double-blind peer review may not actually eliminate bias, hence researchers feel that it is better to switch to open peer review.

What is your opinion towards both single and double-blind peer review? Do you think double bind peer review is any better than single-blind peer review? Or do you think it is time to switch to open peer review? Please share your thoughts with us in the comments section below.

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