

LIPID UNIVERSE

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Infusing a Plant-based Omega-3
Prebiotic into Gut-brain Wellness Formulations

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Important Figures

Enzymatic Fatty Acid Ethyl Esters
Synthesis Using Acid Soybean
Oil and Liquid Lipase Formulation

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Members' Page



Oil Technologists' Association of India (North Zone)





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Editor-in-chief desk.....



Dear Friends,

Every quarter, as this journal takes shape on my desk, I am struck by how quickly the boundaries of our discipline are being redrawn. Oils and fats were once discussed almost entirely in the vocabulary of yield, refining loss, shelf life and price. Today the conversation has widened to include the gut microbiome, enzyme engineering, front-of-pack labelling and the contest between the food plate and the fuel tank. This issue is, in many ways, a map of that widening.

Our lead article on plant-based omega-3 deserves careful reading. The work reported from Laval and Southampton suggests that stearidonic acid-rich oil does more than raise omega-3 intake: it appears to shift the gut microbiota towards a less inflammatory profile and to prompt the bacteria themselves to manufacture endocannabinoid-like mediators. For Indian formulators the implication is practical. Marine supply is finite and its price rising; a stable plant-based source opens categories previously closed to us. It also places a fresh burden on our laboratories, since claims of this kind must be underwritten by fatty acid profiling and stability data, not by marketing enthusiasm.

The contribution from the Rio de Janeiro State University group is an equally welcome addition. Acid oils, high in free fatty acids, have long been a nuisance stream for the refiner and a poor substrate for alkaline catalysis. That soluble liquid lipases can esterify and transesterify them in a single step, near 30°C and with ethanol rather than methanol, points to a route that is cheaper, milder and fully renewable.

That optimism must be read alongside the trade news in these pages. With maize prices lifted by the ethanol-blending programme while soybean trades below its support price, farmers are making an entirely rational choice, and acreage has slipped as a result. India already imports some sixty to sixty-five per cent of its edible oil requirement. The answer, to my mind, lies less in prohibition than in raising oilseed productivity per hectare and improving realisation from meal. Alongside this, the Romanian adoption of Nutri-Score and the approach of the European deforestation regulation remind us that our industry is now judged on provenance and presentation as much as on composition.

MCPD and glycidyl esters - a subject on which Indian refiners must build capability before regulation, not after it. Readers will also find the tables of important figures, health news, a note on fennel seed essential oil and members' page interesting and informative.

Many thanks to our contributors, our advertisers and the editorial team. As always, I invite members to send in research notes and plant experiences; this journal is at its best when it carries the voice of the shop floor as readily as that of the laboratory.

Warm regards,

Yours truly
C.S. Joshi
Editor-in-chief

Editor-in-chief desk.....

Editor's desk.....



Dear Readers,

A new technology known as Infused Technology in today's world has become very vital to mankind. It revolutionizes lipid chemistry by converting water- insoluble and fat- soluble nutrients into a stable water- soluble system. For omega-3 fatty acids from plant based Ahiflower oil and Marine oils, this breakthrough overcomes low bioavailability, rapid oxidation and serve beverage formulation limits.

To produce bio-diesel now-a- days, enzymatic transesterification is used to synthesize and modify fatty acid esters because lipase biocatalysts operate at mild temperatures, handle high free fatty acid feedstocks without forming unwanted soaps, yield pure products, and allow easy separation. While it's main cost drawback is the high price of enzyme, it is balanced by lower energy use, easy waste- feedstock conversion, gentle operating condions and use of immobilized enzymes for reuse accross multiple batches (to reduce net expenses).

On the trade news, the important issues are the global market analysis of commodities and their byproducts, traders urge Government to ban use of maize and other food items to make biofuel so that farmers could stick to production of oilseeds and pulses for self- sufficiency and avoiding import from other countries ; and high- oleic soybeans are more beneficial than saturated fat products to dairy farmers because they find growing market opportunities.

On the health news, the precise and high impact issues are (a) fat- absorbing microbeads may promote weight loss by increasing fat excretion, and (b) how omega-3 fatty acids are different from omega-7 fatty acids. While omega-3 focuses more on heart and brain health, whereas omega-7 has more benifits towards skin, hair and eye health. And eventually both are supportive to overall health.

Essential oils play a critical role in lipid technology as penetration enhancers for the active ingredients. This issue includes Fennel seed essential oil which has anti- aging properties and it works effectively to deal with epidermis to strengthen, protect, re-energise to make the skin radiant glow.

Our member page speaks about hypertension; and nutrition based on an integrated method which combines the approaches by targetting diet, stress, daily habits and medications together as per human vatta, pitta, kapha nature following Ayurveda.

Concluding, this issue discusses the latest trends and innovations in the lipid research, and trust our readers will find these insights compelling.

With heartiest regards,

Dr. S. Adhikari
Editor

Editor's desk.....

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INFUSING A PLANT-BASED OMEGA-3 PREBIOTIC INTO GUT-BRAIN WELLNESS FORMULATIONS

Infusd's technology enables more food and beverage products to access Ahiflower's benefits, reports Greg Cumberland, Vice President of Science and Regulatory at Natures Crops International

Canadian gut microbiome researchers at the University of Laval have recently discovered a novel gut balancing effect that's driven by omega-3 SDA-rich Ahiflower oil's unique fatty acid composition. The researchers have recognised Ahiflower oil's effects in the human gut as "aligning with the criteria accepted to define a food supplement as a prebiotic."

They showed that Ahiflower oil shifts the gut microbiome "catalogue" favourably to a less inflammatory state, raising levels of beneficial *Bacteroides* microbiota in a simulated human gut model. They discovered a novel gut microbiome-mediated mechanism for SDA (stearidonic acid) to promote a beneficial gut "biofactory" for commendamide, an endocannabinoid-like mediator linked to calming gut inflammatory responses.

This will create category and brand-differentiating commercial opportunities for early adopters and product formulators looking to grow beyond typical EPA/DHA omega-3 ingredients — addressing consumer gut-brain support needs in mood, sleep, immune and cognitive performance segments.

Industry market research experts have identified gut-brain wellness as being among the fastest-growing categories in 2024 (+6–8% year-on-year). Using a plant-based omega-rich oil also confers greater oxidative stability and helps to raise omega-3 intake levels without the off-putting sensory challenges typically associated with conventional EPA/DHA sources.

As announced in July 2024, the Halifax-based water-soluble lipid ingredient innovator, Infusd Nutrition,

has pioneered a fully clean-label process enabling the water solubility of fat-soluble and insoluble ingredients at high payloads with proven stability and functionality. Infusd Nutrition's patent-pending 100% natural plant-based oil solubility system also offers more than twice the bioavailability of conventional emulsions and more than four times that of straight omega-3 oils. Infusd's already low-cost solution dramatically improves the cost-per-serving equation in food or beverage formulations.

Ahiflower oil brings "sense and sustainability" to a wider range of food and beverage applications that have typically struggled to bear any omega-3 related claims ... let alone the hormonal balancing and procollagen synthesis benefits attained with Ahiflower oil's omega-6 GLA content.

Gut Microbes as Biofactories

The gut microbiota is known to produce endocannabinoid-like metabolites (such as commendamide) that play a big role in energy processing, inflammation and mood regulation; however, these are not usually derived from processing omega-3 polyunsaturated fatty acids (PUFA). CBD and THC, for example, are strong cannabinoids in and of themselves unrelated to omega-3 fatty acids.

This study provided the first direct evidence to demonstrate the capacity of human gut bacteria to produce this class of compound from omega-3 PUFA. This happened specifically after exposure to Ahiflower oil and was subsequently associated with the SDA metabolite N-stearidonoyl-ethanolamine (SDEA).

This was done using a novel ex vivo fermentation system (M-SHIME) that mimics lumen and mucosal

gut microbial metabolism dynamics, composition and products in a simulated human ileum and ascending colon in a time-dependent manner.

The noted effects occurred from faecal samples taken from four human donors that were then inoculated with 1200 mg/day of Ahiflower oil and fermented for 14 days after a 1-week control (CTRL) period. The fermenting gut microbial composition and metabolite changes were grouped into week-1 (days 8–14) and week-2 (days 15–21) periods for analysis (and further into two clusters [C1 and C2]).

Gut-brain Associations from Ahiflower Oil

Ahiflower oil treatment generally upregulated beneficial *Bacteroides*, *Parabacteroides* and *Phascolarctobacterium* genera (with notable probiotic properties) and, specifically, *Akkermansia muciniphila* in one cluster, while downregulating all but one *Clostridia* taxa, *Actinomycetia* genera and *Bifidobacterium*.

The Ahiflower oil upregulated several taxa noted as secondary probiotics, including *Bifidobacterium*. (*Clostridia* downregulation by fish oil has been noted in this same system and is a beneficial anti-inflammatory GI tract response.)

These changes account for and explain the significant short-chain fatty acid (SCFA) increase in propionate and decrease in acetate in both clusters, with the propionate:butyrate ratio increasing greatly in C2 and causing “an enhanced metabolic response.” The significant elevation of the endocannabinoid mediator commendamide occurred in sync with Ahiflower oil’s stimulation of *Bacteroides* in the lumen of the ileum in both clusters.

The authors observed: “This dietary supplement not only exhibits prebiotic-like effects, but also fosters the remarkable and previously understudied capability of gut microbiota to biotransform dietary fatty acids into bioactive endocannabinoid-like mediators.”

Infusing a Plant-based omega-3 Prebiotic into Gut-brain Wellness Formulations

Ahiflower oil stimulates the capacity of the gut microbiome to produce SDEA, an endocannabinoid-like molecule, which in turn activates nuclear receptor targets such as PPAR- α ; this is known to regulate hepatic lipogenesis and, hence, reduce lipid accumulation in the liver.

Other N-arachidonylethanolamines (NAEs) — including arachidonic, oleic, linoleic and palmitic acid — are elevated in the stools of people with Inflammatory bowel disease (IBD) and they grow *Proteobacteria* at the expense of *Bacteroides*.

However, this study is the first to describe the actual formation of potentially hepatoprotective SDEA by gut microbiota. The authors concluded: “We anticipate that the human ex vivo data presented here will pave the way to future dietary intervention studies that explore the potential therapeutic effects of SDA-containing oils.” “This will identify specific populations that may experience the benefits of this fatty acid or *Buglossoides arvensis* oil, either directly or via the formation of SDEA and other endocannabinoid-like metabolites.”

Interestingly, this research supports an earlier 2017 finding from the University of Illinois’ Decision Neuroscience Lab that measured the brain mass and frontal parietal neocortex integrity of healthy seniors using MRI scans.

The researchers asked which circulating omega-3 levels were most responsible for the highest-performing executive function in these adults and highest brain integrity. They found that omega-3 ALA/SDA levels, not EPA/DHA levels, mediated the highest-quintile outcomes.

Ahiflower oil is the richest-available combined ALA+SDA source with a total fat content of more than 60%. The Laval research team’s findings may give more mechanistic insights into how Ahiflower

SDA's prebiotic and gut inflammation calming interactions are further translating to gut-brain axis wellness outcomes.

The road (or calmer GI tract) ahead

As David Giffin, chemical engineer and cofounder of Infusd Nutrition has noted: "Typical fish and algal oils have been harder to use in water-based beverages owing to inclusion limits and/or short shelf-life constraints before sensory challenges set in." Think kombuchas, kefirs and other gut balancing drinks, or healthy hydration/electrolyte balancing sports nutrition drinks.

Giffin noted: "In a market that has seen rapidly rising prices for omega-3 ingredients, a carrier system that enables greater bioavailability of the active ingredient in foods and beverages means that meeting daily omega-3 intake goals can be achieved at considerably lower costs." Beverage and food categories previously considered unreachable to bring omega-3 wellness benefits with supporting ALA nutrient content claims are now open.

Coupling these two disruptive innovations — Infusd's game-changing water-soluble lipids delivery solutions

and plant-based Ahiflower oil's unique prebiotic and gut-brain support — the road for innovative approaches is wide open.

The Skinny on the New Gut Microbiome Findings

Ahiflower oil at 1.2 g/day in an inoculated human gut lumen and mucosal microbiota incubation model favourably modulates the gut microbiome by raising *Bacteroides* and lowering *Clostridia*, significantly raising SCFA propionate while lowering acetate and causing a novel discovered production of endocannabinoid-like mediator commendamide.¹ The authors stated: "Our findings suggest a more targeted and selective influence of Buglossoides oil, aligning with the criteria accepted to define a food supplement as a prebiotic."

Reference

C. Roussel, et al., "Human Gut Microbiota and Their Production of Endocannabinoid-Like Mediators are Directly Affected by a Dietary Oil," *J. Gut Microbes* 16(1), 2335879 (2024).

Source: Nutraceutical Business Review

TRADE NEWS

Voluntary Adoption of Nutri-Score Approved in Romania

Summary

Romanian consumers will soon see Nutri-Score front-of-pack labels on food packages, following the government's decision to adopt the system after years of uncertainty. Nutri-Score rates the healthiness of food products with a color and letter system based on fat, sugar, salt, and calorie content, and Romania joins other countries in requiring producers to apply the label to all products within a certain time frame.

By the end of the year, Romanian consumers will begin to notice a new front-of-pack label (FOPL) on food packages available for sale in the country.

The Romanian government announced the adoption of Nutri-Score after concluding a public consultation on the new rules for introducing the FOPL.

The decision brings an end to years of uncertainty about the country's position on Nutri-Score adoption.

See Also: France Adopts Nutri-Score Labels

Nutri-Score is a traffic-light-style food label that uses a combination of five coordinated colors and letters to rate the healthiness of a packaged food item based on its fat, sugar, salt, and calorie content per 100-gram or milliliter serving. A "Green A" indicates the healthiest option, while a "Red E" denotes the least healthy.

All Nutri-Score adopters in Romania will act voluntarily. Still, as in other countries adopting Nutri-Score, Romanian regulations require producers who choose to use Nutri-Score on one product to apply it to all products under the same brand within 24 to 36 months, depending on the number of products.

Romanian food producers and retailers will be required to follow the procedures and rules established by Santé Publique France (the French

National Public Health Agency), including graphic standards and usage protocols.

The best extra virgin olive oils, ranked.

Olive Oil Times World Ranking

Operators who fail to comply with the rules (e.g., providing incorrect nutritional data, misusing the logo) may have their rights revoked, face audits or be subject to sanctions or legal action.

The rules harmonize the use of Nutri-Score across all adopting countries. Alongside France and now Romania, the list includes Germany, Switzerland, Belgium, Luxembourg, the Netherlands, Spain and Portugal.

Recommended	Opposed
France	Italy
Belgium	Greece
Luxembourg	Czech Republic
Netherlands	Latvia
Germany	Cyprus
Spain	Hungary
Portugal	
Switzerland	
Romania	

According to the international food product database Open Food Facts, which contributed to the design of the Nutri-Score label, the FOPL now appears in thousands of supermarkets and retail chains.

In countries where Nutri-Score has not been officially adopted such as Slovenia, Austria, and Ukraine some producers and retailers have voluntarily begun displaying it on part or all of their food packaging.

While the number of adopting countries continues to

grow, Nutri-Score remains controversial in several parts of Europe.

Government and institutional officials in Italy, Greece, Cyprus, the Czech Republic, Hungary, and Latvia have repeatedly opposed Nutri-Score.

Despite significant differences in how their concerns are expressed, these countries share the belief that Nutri-Score parameters penalize local food specialties or products widely recognized as healthy when consumed in appropriate portions.

Olive oil has long been at the center of the heated European FOPL debate.

While the latest update to the Nutri-Score algorithm raised all grades of olive oil to a "Light-green B," Nutri-Score founder Serge Hercberg has clarified that olive oil will never receive the highest rating due to its total fat content.

As a result of this debate, Spain has introduced Nutri-Score, and at the same time, it has exempted olive oil producers and distributors from labeling their packaging with the FOPL.

After Nutri-Score was updated, several large food producers began distancing themselves from the logo, starting with the French-based food corporation Danone. More recently, the Swiss giant Nestlé also announced its intention to drop the label from some products in Switzerland.

For a few years, Nutri-Score has been the front-runner of an expected decision by the European Commission on the introduction of a mandatory FOPL across the European Union. The process was stalled in Brussels as the issue was dropped as a legislative priority.

The new European Commission, which formed last autumn, showed no intention to pursue a harmonized FOPL.

The new Romanian decision will become effective 60/ days after its publication in the country's official gazette.

Source: Olive Oil Times

Traders urge govt to ban use of food items for production of biofuel

The All India Edible Oil Traders Federation has urged the government to ban the use of food items for the purpose of production of biofuel. Recently, after the government cut the import duty on crude edible oil, the prices of edible oil have come down and consequently the reports suggest, Indian farmers now prefer to grow maize instead of oilseeds like soybean, cotton and groundnut for better remunerative prices. India, the largest importer of edible oils, imports about 60% to 65% of its domestic requirement.

As per reports, farmers are preferring to sow maize instead of soybean (the former is used for ethanol production) as despite of minimum support price (MSP) of Rs 4,892 per quintal for soybean, prices have crashed 10% to 20% since the start of the new marketing year in October 2024.

Even as cooking oil prices are relatively higher than last year, soybean prices have remained below the MSP due to lower realisation from soybean cake, which is also a reason for farmers turning away from oilseeds.

As of June 20, soybean acreage is 2% lower than last year. This has prompted Agriculture Minister Shivraj Singh Chouhan to connect with farmers in key producing states—Madhya Pradesh, Rajasthan and Maharashtra—and promise to help them increase productivity, which has been stagnant for some time. Chouhan has promised farmers more research on increasing productivity per hectare, genome editing for improved seed varieties, new technology to prevent root rot, and mechanisation due to labour shortage.

It is learnt that the agri ministry has also proposed to the petroleum ministry, which oversees ethanol production, to limit maize sowing in sugarcane-growing areas without compromising on acreage of other crops like soybean and pulses. Following the government's push to use maize for biofuel, the all-India average prices of maize have risen from 14,000-15,000 to 24,000-25,000 per tonne in the past four years, mainly due to the government's ethanol-

blended petrol programme.

Shankar Thakkar, president of the Edible Oil Traders' Federation has said that the government has implemented several schemes related to increasing the production of oilseeds and pulses, but the prices remain fluctuating, which has led the farmers to increase the production of maize fetching them good remunerative price.

“If the government wants to make the country self-sufficient in terms of pulses and oilseeds, then the use of maize and other food items to make biofuel will have to be banned, only then farmers will stick to the production of oilseeds and pulses and India will be able to become self-sufficient, otherwise every year the production of pulses and edible oilseeds will keep decreasing and we will have to import from other countries,” rued Thakkar.

Source: *FnBnews.com*

Kazakhstan expected to continue ramping up production of oilseeds



Kazakhstan has seen a shift from wheat and other grains towards greater oilseed production.

Kazakhstan's oilseeds output is expected to continue increasing, according to a report by the US Department of Agriculture (USDA). Over the last five years, Kazakhstan had undergone a gradual but strategic shift from wheat and other grains towards greater oilseed production, particularly sunflowers in the north and eastern parts of the country, the 25 July report said.

This transition has been driven by economics, weather and government policy, according to the USDA Foreign Agricultural Network (FAS) 'Oilseed Production in Kazakhstan' report. “Favourable yields and decent profit margins have motivated farmers to plant more oilseeds.”

Average sunflower yields had increased steadily, rising from 0.8M tonnes/ha in 2014 to 1.5M tonnes/ha in 2024, while other oilseed crops – including flaxseed, rapeseed and safflower – had an average yield of 1.2M tonnes/ha last year. “This improvement reflects the adoption of higher-quality seed varieties and better agronomic practices, particularly in northern regions,” the USDA report said.

Meanwhile, grain production in some lower-yielding parts of the country had become less viable due to climate stress and soil degradation. The fact that the same harvesting machinery could be used in both wheat and sunflower production was another key factor in the increased interest in sunflowers. “At the same time, sunflower production offers farmers a larger time window for planting and harvesting that doesn't directly compete with wheat and other cereal production,” the report said.

In addition to the economic and weather-related factors spurring increased oilseed production, the Kazakh government's new agri-food strategy is also contributing to this expansion, according to the report.

The government's strategy has three core priorities aimed at: crop diversification; value-added processing and an increase in value-added agricultural exports. In support of this strategy, the national oilseed producers' association has set a goal to expand oilseed cultivation to 4M ha over the next five years (2025-29).

According to Kazakhstan's official statistics, oilseed planted area expanded from 2.8M ha in 2020 to over 3.3M ha in 2025/2026, with sunflower the leading crop.

As part of the strategy to promote oilseed production, the Kazakh government was also giving

farmers a 22,000 tenge (about US\$48/tonne) subsidy when they delivered sunflowers to local processors. The measure was financed through a 20% export duty on sunflower seeds – set at a minimum of •100 (US\$116)/tonne - that generated 9.6bn tenge (US\$21M) in its first year.

Alongside ramping up production of sunflowers and other oilseeds, the country was also investing in downstream infrastructure to transform raw production into high-value exports. Between 2024-2025, the government allocated 18bn tenge (approximately US\$40M) to support the construction and modernisation of oil processing facilities. As a result of these investments, Kazakhstan's refining capacity more than doubled – from under 300,000 tonnes in 2021 to an estimated 600,000 tonnes in 2025.

In parallel to the increase in capacity, total vegetable oil production had been increasing for the past decade from 180,000 tonnes in 2014/15 (September-August) to over 560,000 tonnes in 2023/24. "This expansion in processing capacity aligns with the government's goal of moving beyond raw commodity exports toward higher-value agricultural products," the USDA said.

According to Kazakhstan's official trade statistics, exports of vegetable oils and meal – mostly oil and meal from sunflowers –increased from less than 200,000 tonnes in 2014/15 to a record volume of more than 1M tonnes MT in 2023/24. Export earnings also surged, reaching a record of nearly US\$580M in 2023/24.

In 2023/24, Uzbekistan was the largest export destination for Kazakh vegetable oils and meals, accounting for nearly 380,000 tonnes or a little more than one-third of the total. The next largest destinations were China, Tajikistan and Latvia.

Over the last two years, rail shipments of sunflower oil to China increased from 50–70 wagons/month to over 300–350/month due to the adoption of containerised flexitanks and the modernisation of unloading terminals at Khorgos, according to industry sources. These improvements had significantly

boosted reliability and efficiency in oil exports. More than 20 Kazakh processing plants were now registered for export to China.

Five large oilseed processing plants with a total capacity of 421,000 tonnes were being built in the country, the Ministry of Agriculture Aidarbek Saparov was quoted as saying in a 21 July APK-*Inform* report. Saparov noted that sunflower oil production increased by 15% in 2024, which was twice domestic demand. In the first six months of this year, production reached 388,000 tonnes – 21.3% more than in the same period last year. In addition, 294,000 tonnes of sunflower oil were exported between January and March – a 41% increase compared to last year.

Source: Oils & Fats International

Burcon NutraScience begins selling canola protein isolate



VANCOUVER, BC. — Burcon NutraScience Corp. has made its first commercial sale of Puratein C, a canola protein isolate. Burcon's proprietary technology upcycles byproducts from solvent-free canola oilseed processing to extract the isolate, which has "exceptional nutritional, functional and flavorful properties," according to the company.

Puratein C, extracted from non-GMO canola seeds grown in North America, contains all nine essential amino acids and delivers a protein digestibility-corrected amino acid score (PDCAAS) of 1.0. It has high solubility, a light cream color and a mild flavor

profile, according to Vancouver-based Burcon NutraScience. Potential applications include baked foods, dairy alternatives, ready-to-drink beverages, meat analogues and sauces. Burcon NutraScience also offers Peazazz, a pea protein isolate, and recently began commercially producing FavaPro, a fava bean protein isolate.

“The first sales of Puratein canola protein mark another step in scaling Burcon’s innovation into the market,” said Kip Underwood, chief executive officer of Burcon. “By leveraging our technology platform, we are creating sustainable, high-quality proteins that drive new opportunities for customers and revenue growth.”

Source: BackingBusiness.com

Dairy Feed Market Offers Stability for High-Oleic Soybeans



A field of Plenish, Pioneer’s line of high-oleic soybeans.

In its short decade-plus existence, the high-oleic soybean oil market has been rocky. While that will continue — both with highs and lows — the dairy feed market could help stabilize demand for high-oleic soybeans.

Today, about half of all high-oleic soybean acres are going into dairy compared to around 5% five years ago, said Roger Theisen, marketing manager for Pioneer specialty crops, including the Plenish high-oleic soybean line. “As I look into the future, I see this market growing,” Theisen said.

This comes after plantings dropped from 1.1 million acres to 800,000 acres from 2023 to 2024, according to the United Soybean Board. “I see that as the new low,” Theisen said. “I see the momentum in this dairy segment. I see some of the downstream edible oil use market increasing, so I expect 2026 to be a much bigger high-oleic soybean market year.”

Theisen also said the decrease in acreage is not associated with the dairy market. In the dairy-focused Northeast, high-oleic soybean acreage has stayed flat to slightly increased. Ever-growing interest in feeding high-oleic is leading many dairy farmers to grow the beans, said Jeff Swartz, director of nutrition at Homestead Nutrition of Lancaster, Pennsylvania.

It’s not a new fascination for dairy, but it’s become easier to get high-oleic beans, Swartz said. With the human edible oil market the original intent for growers, it was hard for dairy farmers to get them for feed. They’re available for purchase today, Swartz said, but it’s still more cost-effective for producers to grow their own since the soybeans carry a premium. Perdue, for example, is offering a premium of \$0.75 per bushel for farms that harvest and deliver, and \$0.85 per bushel for beans stored on farm to meet its oil crush facility needs in 2026, Theisen said.

In 2012, when high-oleic soybeans became commercially available, processors saw opportunity in the human edible oil market, identifying them as a healthier alternative due to higher oleic acid levels. While no foreign high-oleic soybean market has developed, Theisen said other healthful oil substitutes have led to turbulence. These alternatives leave the market open to disturbances from international events.

For example, after a dropoff from the initial interest in high-oleic soybean oil, the market improved again in 2020, Theisen said, because of supply chain interruptions affecting alternatives.

Likewise, the Russia-Ukraine war halted production of high-oleic sunflower oil from Ukraine, leading to more interest in the soybean oil alternative. “It’s no

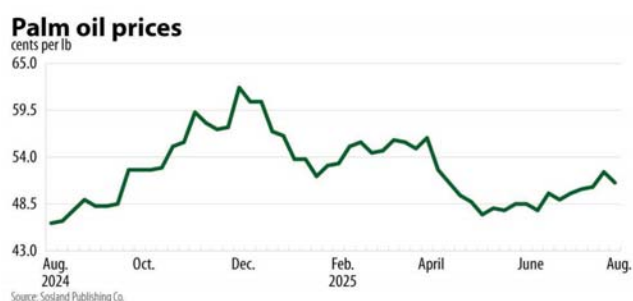
different than the economics in a commodity market,” Theisen said. “When the economics favor one product over another, you’ll see fluctuations.”

Swartz explained that high-oleic soybeans are beneficial to dairy farmers because they allow for feeding more total fat while buying in less protein. “Something like an Energy Booster 100 would be probably the closest thing to the beans,” Swartz said. “That’s primarily stearic acid, which would be the saturated product ... but that’s more of like a pure fat-type product. That’s not going to have the protein in it.”

In a dairy market increasingly driven by components, being able to increase fat in feed without worrying about suppressing butterfat is important. And being able to grow high-oleic soybeans with a stable destination is important for that bean industry. “This momentum in the dairy market is incredible,” Theisen said.

Source: Lancaster Farming

Conditions remain ripe for palm oil price volatility



The global palm oil market is managing a slew of conundrums. While it is the most consumed vegetable oil in the world, it also is considered by some groups as “the world’s most hated crop” due to environmental and labor concerns. It generates ire and support from certain health-conscious groups, as the palm oil fruit offers both seed-oil and seed-oil-free extracts.

It also is one of the most prolific crops on the planet,

but the advancing age of both the trees and its workforce along with the shallow replanting efforts in the top producing countries has cast a weak outlook for a crop that provides 40% of all the vegetable oil used in the world, while only using 6% of the world’s oilseed crop area to produce it.

Palm oil is one of the most volatile commodities from a market perspective. In the past year, it has catapulted from being the least expensive vegetable oil on the global market to the most expensive oil and then back down to the least expensive.

Originating in West Africa, the oil palm tree was cultivated in Southeast Asia in the early 20th century by the British government which championed the oil as a suitable replacement for less accessible and more expensive oils like tallow and whale oil. Today, the Southeast Asian countries of Indonesia and Malaysia produce about 85% of the world’s palm oil supplies, and its uses range from cooking oil to industrial applications.

Food manufacturers around the world value palm oil’s versatility. When it is refined, palm oil is odorless and color-free and has a neutral flavor. Its semi-solid texture at room temperature provides suppleness, and it resists oxidation, which helps extend shelf life. Plus, it is heat stable, making it a suitable component for a wide array of food products.

Palm oil is not the most consumed edible oil in the United States; that title belongs to soybean oil. But it is a significantly used commodity, making up approximately 50% of US grocery store items, from frozen pizzas to lipsticks.

The US Department of Agriculture in its recent Oilseeds report raised the projection for 2025-26 US imports of palm oil by 12% to 1,850,000 tonnes due to increased food use. Some food companies, hoping to capitalize on the current trend that vilifies seed oils, have turned to palm oil as a viable and inexpensive replacement for soybean and canola oils. But it must be noted the fruit of the oil palm tree produces two types of oil. Crude palm oil, which is produced by squeezing the fleshy fruit from the oil

palm tree, is considered a seed-free oil. But palm kernel oil, which is produced by extracting oil from the seed of the same fruit, is classified as a seed oil. Plus, palm oil contains a significant amount of saturated fat, which may contribute to heart disease.

Also challenging for many global manufacturers is the environmental concerns about palm oil production. Conservation groups have criticized palm oil producers for deforesting the habitats of endangered animals like the orangutan and pygmy elephant. Accusations of child labor and slave-like conditions also plague the commodity.

25August12_MI_PalmOilPrices (003).

In 2023, the European Union Commission adopted an initiative called the Regulation on Deforestation-free Products (EUDR) as part of its European Green Deal platform, which prohibits the entry of products on the EU market unless the procurer can prove the products did not originate from nor contribute to deforestation. The Commission plans to enforce the regulation on Dec. 30 for major operations and on June 30, 2026, for smaller producers.

The deforestation regulations, however, may inadvertently exacerbate the outlook for shrinking palm oil production. Most trees in the major producing areas are old and need to be replanted as older trees do not produce as much fruit and eventually grow too tall for farmers to access. But new trees take several years before they produce profitable fruits, which limits replanting, and expanding crop area to plant new trees while tending to the current crop is difficult under the EUDR guidelines.

All these factors contribute to the volatility of the palm oil market. Prices jumped to two-year highs in December 2024 on ideas adverse weather and increased domestic usage in top-producing countries may limit supplies available to the global market, according to data collected by Sosland Publishing Co. Since then, palm oil has returned to its typical discount status to other global vegetable oils. But the eventual enforcement of the EUDR and the recent enactment of US tariffs may continue to support a volatile environment for this widely used commodity.

Source: Food Business News

IMPORTANT FIGURES

Table 01: Soybeans: World Supply and Distribution

Thousand Metric Tons

	2022/23	2023/24	2024/25	2025/26
Production				
Brazil	162,000	154,500	172,500	180,000
United States	116,221	113,273	119,047	115,989
Argentina	25,000	48,210	51,108	50,000
China	20,284	20,840	20,650	20,900
India	12,411	11,875	12,882	11,027
Paraguay	10,250	11,000	10,200	12,100
Russia	5,996	6,800	7,050	9,000
Other	26,048	29,950	34,609	30,445
Total	378,210	396,448	428,046	429,461
Imports				
China	104,500	112,000	108,000	113,000
European Union	13,127	13,550	14,710	13,800
Mexico	6,451	6,457	6,434	6,700
Argentina	9,059	7,787	6,324	7,050
Egypt	1,993	3,321	4,543	4,600
Turkey	2,888	3,252	4,183	4,000
Thailand	3,238	3,428	4,190	4,200
Vietnam	1,858	2,265	2,609	3,050
Pakistan	571	997	1,939	3,000
Japan	3,332	3,099	3,243	3,100
Other	21,485	22,343	22,971	23,842
Total	168,502	178,499	179,146	186,342
Exports				
Brazil	95,504	104,170	103,142	115,000
United States	53,864	46,350	51,495	41,368
Paraguay	6,495	7,987	6,405	8,200
Argentina	4,185	5,114	7,874	9,000
Canada	4,240	4,861	5,551	5,300
Other	7,470	9,364	9,863	8,210
Total	171,758	177,846	184,330	187,078
Crush				
China	96,000	99,000	103,500	109,000
United States	60,199	62,196	66,546	72,121
Brazil	53,409	54,405	58,162	61,500
Argentina	30,341	36,583	43,236	42,000
European Union	14,300	14,500	15,400	14,800
India	10,300	11,300	11,300	9,775
Mexico	6,650	6,530	6,650	6,850
Russia	5,400	5,900	6,225	6,600
Egypt	2,200	3,250	4,500	4,600
Paraguay	3,450	3,000	3,700	3,600
Pakistan	650	950	1,800	2,900
Bolivia	3,300	2,600	3,225	3,100
Turkey	1,700	2,300	2,850	2,800
Thailand	2,100	2,400	2,700	3,000
Ukraine	1,500	1,800	2,800	2,900
Other	24,268	24,531	26,542	26,940
Total	315,767	331,245	359,136	372,486
Ending Stocks				
China	32,341	43,311	44,489	44,369
Brazil	36,819	29,761	37,688	37,688
Argentina	16,999	24,049	24,671	23,821
United States	7,190	9,319	8,840	8,978
European Union	1,262	1,300	1,568	1,552
Other	7,230	7,359	8,677	8,917
Total	101,841	115,099	125,933	125,325

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 02: Soybean Meal: World Supply and Distribution

Thousand Metric Tons

	2022/23	2023/24	2024/25	2025/26
Production				
China	76,032	78,408	81,972	86,328
United States	47,621	49,084	53,019	57,186
Brazil	41,488	41,859	44,383	47,478
Argentina	23,666	28,352	33,508	32,340
European Union	11,297	11,455	12,166	11,692
India	8,240	9,040	9,040	7,820
Mexico	5,255	5,159	5,255	5,411
Other	34,786	36,502	42,391	44,176
Total	248,385	259,859	281,734	292,431
Imports				
European Union	15,997	16,564	20,609	19,600
Vietnam	4,724	6,033	5,703	6,550
Indonesia	5,434	5,055	6,179	6,400
Philippines	2,824	2,967	3,189	3,300
Thailand	3,141	2,770	2,939	3,000
Mexico	1,670	1,937	2,345	2,700
Iran	1,185	2,985	2,805	2,600
United Kingdom	1,762	1,976	2,529	2,500
Colombia	1,603	1,585	2,030	2,350
Ecuador	1,771	1,891	2,100	2,200
Other	23,200	25,836	27,261	29,641
Total	63,311	69,599	77,689	80,841
Exports				
Argentina	20,764	24,891	29,780	29,000
Brazil	21,334	22,722	23,390	25,000
United States	13,196	14,564	16,396	18,416
Bolivia	2,155	1,546	2,006	2,000
Paraguay	1,992	1,683	2,176	2,000
Other	7,625	8,817	9,114	8,200
Total	67,066	74,223	82,862	84,616
Domestic Consumption				
China	75,050	77,150	80,850	85,150
United States	34,946	35,068	37,405	39,485
European Union	26,642	27,042	31,242	30,942
Brazil	20,000	20,000	20,500	21,800
Vietnam	5,785	6,640	7,295	8,095
Mexico	6,930	7,080	7,450	8,090
India	6,625	7,075	7,185	7,130
Indonesia	5,580	5,200	5,900	6,350
Thailand	4,750	4,575	4,800	5,150
Egypt	2,700	3,000	3,800	4,050
Iran	3,550	4,810	5,100	4,700
Russia	3,650	3,900	4,100	4,300
Argentina	3,450	3,500	3,525	3,600
Japan	3,550	3,521	3,505	3,465
Philippines	2,930	3,000	3,220	3,330
Other	40,899	43,533	47,054	51,633
Total	247,037	255,094	272,931	287,270
Ending Stocks				
Brazil	3,817	2,972	3,470	4,158
Argentina	2,297	2,259	2,741	2,731
European Union	510	836	1,717	1,467
China	937	794	943	1,271
Turkey	422	466	572	645
Other	6,190	6,987	8,501	9,058
Total	14,173	14,314	17,944	19,330

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 3: Soybean Oil: World Supply and Distribution

Thousand Metric Tons

	2022/23	2023/24	2024/25	2025/26
Production				
China	18,240	18,810	20,100	21,168
United States	11,897	12,289	13,253	13,996
Brazil	10,580	11,055	11,842	12,540
Argentina	5,995	7,251	8,626	8,379
European Union	2,717	2,755	2,926	2,812
India	1,854	2,034	2,034	1,760
Mexico	1,227	1,205	1,227	1,264
Other	8,215	8,610	10,052	10,439
Total	60,725	64,009	70,060	72,358
Imports				
India	3,968	3,308	5,471	4,650
Canada	147	573	637	900
Bangladesh	703	649	943	600
Morocco	514	488	626	650
European Union	641	592	757	650
Peru	535	560	612	590
Korea, South	353	447	482	450
Algeria	490	485	564	450
Colombia	242	317	384	375
China	365	381	296	300
Other	3,019	2,733	3,525	3,533
Total	10,977	10,533	14,297	13,148
Exports				
Argentina	4,137	5,533	7,099	6,450
Brazil	2,687	1,352	1,487	1,600
China	111	104	318	900
European Union	915	659	708	850
Russia	750	760	750	700
Paraguay	523	497	621	600
Ukraine	277	345	523	530
Other	2,342	2,562	3,740	2,859
Total	11,742	11,812	15,246	14,489
Domestic Consumption				
China	17,900	18,900	20,500	20,500
United States	12,070	12,317	12,207	13,651
Brazil	8,300	10,200	10,410	11,050
India	5,400	5,175	6,645	6,590
European Union	2,405	2,630	3,005	2,705
Argentina	1,660	1,770	1,980	1,980
Mexico	1,305	1,270	1,310	1,390
Bangladesh	975	1,010	1,200	1,100
Canada	320	685	750	1,060
Egypt	560	510	730	870
Algeria	750	765	780	820
Pakistan	360	285	620	650
Korea, South	565	600	650	645
Morocco	510	505	600	630
Peru	540	550	585	595
Other	5,795	5,724	6,352	6,932
Total	59,415	62,896	68,324	71,168
Ending Stocks				
India	597	748	1,581	1,381
China	981	1,168	746	814
United States	729	703	792	833
European Union	601	659	629	536
Brazil	594	177	207	197
Other	2,347	2,228	2,515	2,558
Total	5,849	5,683	6,470	6,319

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 04: Soybeans and Products: World Trade

Million Metric Ton

	Marketing Year	Meal, Soybean		Oil, Soybean		Oilseed, Soybean	
		2024/25	2025/26	2024/25	2025/26	2024/25	2025/26
Exports							
North America		16,709	18,747	1,289	609	57,046	46,678
South America		57,356	58,007	9,830	9,215	121,070	134,602
South Asia		1,804	890	32	27	12	20
India	(Oct-Sep)	1,781	850	27	20	12	20
Other		6,993	6,972	4,095	4,638	6,202	5,778
World Total		82,862	84,616	15,246	14,489	184,330	187,078
Imports							
European Union	(Oct-Sep)	20,609	19,600	757	650	14,710	13,800
East Asia		3,425	3,615	933	897	115,144	120,065
China	(Oct-Sep)	45	150	296	300	108,000	113,000
Japan	(Oct-Sep)	1,621	1,700	1	2	3,243	3,100
Korea, South	(Oct-Sep)	1,725	1,725	482	450	1,128	1,160
Taiwan	(Oct-Sep)	34	40	0	0	2,768	2,800
Southeast Asia		19,910	21,210	293	267	10,128	10,850
Indonesia	(Oct-Sep)	6,179	6,400	34	37	2,439	2,750
Malaysia	(Oct-Sep)	1,426	1,400	92	95	727	670
Philippines	(Jan-Dec)	3,189	3,300	60	60	136	150
Thailand	(Sep-Aug)	2,939	3,000	0	0	4,190	4,200
Vietnam	(Jan-Dec)	5,703	6,550	90	60	2,609	3,050
North America		4,525	4,912	974	1,250	7,490	7,690
Canada	(Aug-Jul)	1,448	1,450	637	900	250	310
United States	(Oct-Sep)	732	762	164	150	806	680
Canada	(Aug-Jul)	1,448	1,450	637	900	250	310
Mexico	(Sep-Aug)	2,345	2,700	173	200	6,434	6,700
South America		8,464	9,310	1,780	1,708	8,017	9,020
Argentina	(Oct-Sep)	279	250	107	120	6,324	7,050
Brazil	(Oct-Sep)	5	10	85	100	731	900
Paraguay	(Jan-Dec)	0	0	3	1	4	20
Brazil	(Oct-Sep)	5	10	85	100	731	900
Colombia	(Oct-Sep)	2,030	2,350	384	375	561	530
Central America		2,056	2,275	218	230	320	330
Caribbean		801	1,064	295	311	17	40
Middle East		8,194	8,395	238	318	9,069	7,696
Iran	(Oct-Sep)	2,805	2,600	26	150	2,693	2,150
Israel	(Oct-Sep)	311	320	2	2	266	320
Syria	(Jan-Dec)	252	200	7	2	1	1
Turkey	(Oct-Sep)	1,350	1,950	0	0	4,183	4,000
North Africa		2,222	1,940	1,286	1,395	6,710	7,480
Egypt	(Oct-Sep)	395	450	50	250	4,543	4,600
Other Europe		3,151	3,115	201	236	1,757	1,745
United Kingdom	(Oct-Sep)	2,529	2,500	190	225	1,079	950
Other		4,332	5,405	7,322	5,886	5,784	7,626
World Total		77,689	80,841	14,297	13,148	179,146	186,342

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 05: Palm Oil: World Supply and Distribution

Thousand Metric Tons

	2022/23	2023/24	2024/25	2025/26
Production				
Indonesia	45,000	43,000	45,500	46,700
Malaysia	18,389	19,710	19,380	20,200
Thailand	3,321	3,274	3,740	3,900
Colombia	1,853	1,875	1,900	2,000
Nigeria	1,400	1,500	1,500	1,500
Other	6,795	6,816	6,918	7,161
Total	76,758	76,175	78,938	81,461
Imports				
India	10,045	8,886	7,786	9,050
China	6,190	4,377	3,203	4,175
Pakistan	3,094	2,980	3,325	3,650
European Union	4,576	4,013	3,135	3,500
United States	1,887	1,864	1,542	1,450
Bangladesh	1,610	1,676	1,540	1,600
Philippines	892	1,083	1,406	1,250
Egypt	1,052	1,171	1,301	1,400
Vietnam	1,112	1,071	1,076	1,150
Kenya	848	875	811	900
Other	15,335	14,363	16,234	15,139
Total	46,641	42,359	41,359	43,264
Exports				
Indonesia	28,077	22,273	23,471	23,700
Malaysia	15,355	16,530	15,617	16,350
Thailand	902	878	1,302	1,000
Papua New Guinea	813	669	740	830
Guatemala	883	620	566	650
Other	3,337	3,440	3,322	3,222
Total	49,367	44,410	45,018	45,752
Domestic Consumption				
Indonesia	19,125	21,075	22,375	22,925
India	8,900	8,990	8,800	9,105
Malaysia	3,975	3,667	4,165	4,235
China	5,400	5,000	3,300	4,125
Pakistan	2,995	3,070	3,250	3,600
European Union	4,500	3,890	3,200	3,350
Thailand	2,485	2,485	2,445	2,735
Nigeria	1,790	1,840	1,940	1,940
United States	1,875	1,894	1,525	1,422
Bangladesh	1,600	1,575	1,540	1,650
Colombia	1,500	1,555	1,530	1,615
Philippines	1,000	1,040	1,485	1,390
Egypt	1,060	1,160	1,250	1,365
Vietnam	1,037	1,007	1,040	1,100
Brazil	825	920	950	990
Other	15,776	15,936	17,447	16,926
Total	73,843	75,104	76,242	78,473
Ending Stocks				
Indonesia	5,108	4,761	4,416	4,491
Malaysia	2,312	2,014	2,360	2,475
India	2,419	2,615	1,898	2,098
Colombia	856	842	717	752
Thailand	499	412	409	576
Other	5,800	5,370	5,251	5,159
Total	16,994	16,014	15,051	15,551

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 06: Rapeseed and Products: World Supply and Distribution

Thousand Metric Tons

	Marketing Year	Meal, Rapeseed		Oil, Rapeseed		Oilseed, Rapeseed	
		2024/25	2025/26	2024/25	2025/26	2024/25	2025/26
Production							
China	(Oct-Sep)	11,861	11,448	7,839	7,566	15,800	16,000
India	(Oct-Sep)	6,189	6,399	3,956	4,090	11,520	12,000
Canada	(Aug-Jul)	6,710	7,230	4,821	5,300	19,239	22,000
Japan	(Oct-Sep)	1,231	1,338	884	984	3	3
European Union	(Jul-Jun)	13,509	14,478	9,954	10,668	17,073	20,522
Other		9,795	10,941	6,827	7,660	22,650	25,042
World Total		49,295	51,834	34,281	36,268	86,285	95,567
Imports							
China	(Oct-Sep)	2,810	2,700	2,171	2,150	4,600	3,600
India	(Oct-Sep)	21	5	26	40	0	0
Canada	(Aug-Jul)	1	10	16	20	131	150
Japan	(Oct-Sep)	4	6	23	15	2,138	2,400
European Union	(Jul-Jun)	420	900	295	650	7,964	6,500
Other		6,889	7,576	4,548	4,928	5,165	5,424
World Total		10,145	11,197	7,079	7,803	19,998	18,074
Exports							
China	(Oct-Sep)	32	350	19	90	0	0
India	(Oct-Sep)	1,870	1,500	13	10	0	0
Canada	(Aug-Jul)	5,855	5,950	3,327	3,550	9,387	8,200
Japan	(Oct-Sep)	8	0	5	5	0	0
European Union	(Jul-Jun)	880	1,000	585	600	382	650
Other		2,065	2,634	3,192	3,730	10,054	9,688
World Total		10,710	11,434	7,141	7,985	19,823	18,538
Domestic Consumption							
China	(Oct-Sep)	14,639	13,798	10,350	9,850	20,925	20,225
India	(Oct-Sep)	4,360	4,900	4,005	4,080	11,550	11,975
Canada	(Aug-Jul)	870	1,270	1,330	1,710	11,673	13,000
Japan	(Oct-Sep)	1,221	1,345	895	990	2,134	2,375
EuropeanUnion	(Jul-Jun)	13,100	14,300	9,700	10,500	24,350	26,200
Other		14,609	15,809	8,100	8,751	17,832	19,722
World Total		48,799	51,422	34,380	35,881	88,464	93,497
Ending Stocks							
China	(Oct-Sep)	0	0	1,250	1,026	4,259	3,634
India	(Oct-Sep)	204	208	357	397	539	564
Canada	(Aug-Jul)	154	174	730	790	1,476	2,426
Japan	(Oct-Sep)	89	88	37	41	194	222
European Union	(Jul-Jun)	351	429	273	491	2,243	2,415
Other		628	702	649	756	1,230	2,286
World Total		1,426	1,601	3,296	3,501	9,941	11,547

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 07: Sunflowerseed and Products: World Supply and Distribution

Thousand Metric Tons

	Marketing Year	Oilseed, Sunflowerseed		Meal, Sunflowerseed		Oil, Sunflowerseed	
		2024/25	2025/26	2024/25	2025/26	2024/25	2025/26
Production							
Argentina	(Mar-Feb)	5,592	7,400	2,145	2,536	2,120	2,521
Russia	(Sep-Aug)	16,900	17,500	6,698	6,862	6,732	6,897
Turkey	(Sep-Aug)	1,350	1,250	995	1,306	795	1,044
Ukraine	(Sep-Aug)	13,000	11,000	5,080	4,543	5,290	4,730
European Union	(Oct-Sep)	8,645	8,655	4,108	4,066	3,212	3,170
Other		7,528	9,477	2,382	2,944	2,261	2,761
World Total		53,015	55,282	21,408	22,257	20,410	21,123
Imports							
Argentina	(Mar-Feb)	1	10	0	0	0	0
Russia	(Sep-Aug)	80	70	5	5	1	1
Turkey	(Sep-Aug)	789	1,550	1,042	900	1,236	1,300
Ukraine	(Sep-Aug)	22	30	1	10	1	0
European Union	(Oct-Sep)	582	1,200	2,567	2,600	2,411	2,475
Other		1,135	1,210	4,130	4,656	8,358	7,967
World Total		2,609	4,070	7,745	8,171	12,007	11,743
Exports							
Argentina	(Mar-Feb)	626	850	1,657	1,900	1,686	1,925
Russia	(Sep-Aug)	200	300	2,400	2,300	4,200	4,200
Turkey	(Sep-Aug)	174	125	53	65	1,001	900
Ukraine	(Sep-Aug)	68	35	3,418	2,900	4,744	4,375
European Union	(Oct-Sep)	824	1,200	479	500	691	650
Other		1,480	1,806	758	1,092	1,339	1,621
World Total		3,372	4,316	8,765	8,757	13,661	13,671
Domestic Consumption							
Argentina	(Mar-Feb)	5,230	6,375	500	600	562	562
Russia	(Sep-Aug)	16,800	17,220	4,300	4,500	2,575	2,575
Turkey	(Sep-Aug)	2,027	2,602	2,000	2,100	1,090	1,415
Ukraine	(Sep-Aug)	12,825	11,150	1,800	1,750	440	455
European Union	(Oct-Sep)	8,630	8,565	6,260	6,160	5,213	5,013
Other		7,396	8,793	5,729	6,526	9,222	9,304
World Total		52,908	54,705	20,589	21,636	19,102	19,324
Ending Stocks							
Argentina	(Mar-Feb)	558	743	194	230	116	150
Russia	(Sep-Aug)	697	747	410	477	195	318
Turkey	(Sep-Aug)	80	153	171	212	109	138
Ukraine	(Sep-Aug)	305	150	429	332	241	141
European Union	(Oct-Sep)	340	430	393	399	418	400
Other		563	651	332	314	1,467	1,270
World Total		2,543	2,874	1,929	1,964	2,546	2,417

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 08 Minor Vegetable Oils: World Supply and Distribution

Thousand Metric Tons

	Marketing Year	Oil, Peanut		Oil, Cottonseed		Oil, Olive	
		2024/25	2025/26	2024/25	2025/26	2024/25	2025/26
Production							
China	(Oct-Sep)	3,104	3,104	1,164	1,164	9	10
India	(Oct-Sep)	1,256	1,323	1,311	1,297	nr	nr
Turkey	(Nov-Oct)	7	7	235	185	410	210
United States	(Aug-Jul)	106	130	131	125	16	14
EuropeanU nion	(Oct-Sep)	13	13	29	24	2,112	2,092
Other		1,822	1,728	1,843	1,915	786	952
World Total		6,308	6,305	4,713	4,710	3,333	3,278
Imports							
China	(Oct-Sep)	347	250	0	0	40	45
India	(Oct-Sep)	0	0	1	5	nr	nr
Turkey	(Nov-Oct)	0	0	3	3	30	30
United States	(Aug-Jul)	46	16	1	2	446	425
European Union	(Oct-Sep)	47	60	2	10	202	250
Other		33	40	58	71	518	519
World Total		473	366	65	91	1,236	1,269
Exports							
China	(Oct-Sep)	11	10	8	15	0	0
India	(Oct-Sep)	233	100	0	0	nr	nr
Turkey	(Nov-Oct)	0	0	2	2	79	60
United States	(Aug-Jul)	6	5	20	23	8	10
European Union	(Oct-Sep)	6	6	1	1	847	800
Other		330	314	26	33	420	529
World Total		586	435	57	74	1,354	1,399
Domestic Consumption							
China	(Oct-Sep)	3,440	3,344	1,156	1,149	49	55
India	(Oct-Sep)	1,010	1,180	1,330	1,305	nr	nr
Turkey	(Nov-Oct)	7	7	235	185	400	200
United tates	(Aug-Jul)	143	141	116	102	454	429
European Union	(Oct-Sep)	54	67	30	33	1,395	1,470
Other		1,499	1,468	1,864	1,949	839	886
World Total		6,153	6,207	4,731	4,723	3,137	3,040
Ending Stocks							
China	(Oct-Sep)	0	0	0	0	0	0
India	(Oct-Sep)	200	243	28	25	nr	nr
Turkey	(Nov-Oct)	0	0	14	15	60	40
United States	(Aug-Jul)	11	11	16	18	0	0
European Union	(Oct-Sep)	4	4	0	0	254	326
Other		156	142	120	124	185	241
World Total		371	400	178	182	499	607

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 09: China Oilseeds and Products Supply and Distribution

Thousand Metric Tons

	2022/23	2023/24	2024/25	2025/26
Production				
Oilseed, Peanut	18,330	19,231	19,000	18,400
Oilseed, Rapeseed	16,317	15,800	15,800	16,000
Oilseed, Soybean	20,284	20,840	20,650	20,900
Oilseed, Sunflowerseed	1,741	1,983	1,750	2,200
Other	10,196	9,069	10,611	11,871
Total	66,868	66,923	67,811	69,371
Imports				
Oilseed, Peanut	940	774	448	700
Oilseed, Rapeseed	5,335	5,486	4,600	3,600
Oilseed, Soybean	104,500	112,000	108,000	113,000
Oilseed, Sunflowerseed	266	183	132	125
Other	665	690	332	350
Total	111,706	119,133	113,512	117,775
Domestic Consumption				
Meal, Peanut	4,005	3,973	3,885	3,978
Meal, Rapeseed	13,512	14,519	14,639	13,798
Meal, Soybean	75,050	77,150	80,850	85,150
Other	10,472	10,678	9,249	10,469
Total	103,039	106,320	108,623	113,395
SME				
Meal, Peanut	4,502	4,466	4,367	4,471
Meal, Rapeseed	9,276	9,992	10,074	9,476
Meal, Soybean	73,900	76,000	79,700	84,000
Other	8,435	8,936	8,147	8,886
Total	96,112	99,394	102,288	106,833
Food Use Dom. Cons.				
Oil, Palm	3,100	2,800	1,800	2,625
Oil, Peanut	3,418	3,373	3,440	3,344
Oil, Rapeseed	8,800	9,700	10,350	9,850
Oil, Soybean	17,900	18,900	20,500	20,500
Oil, Sunflowerseed	1,803	1,419	717	827
Other	1,387	1,369	1,367	1,404
Total	36,408	37,561	38,174	38,550
Domestic Consumption				
Oil, Palm	5,400	5,000	3,300	4,125
Oil, Peanut	3,418	3,373	3,440	3,344
Oil, Rapeseed	8,800	9,700	10,350	9,850
Oil, Soybean	17,900	18,900	20,500	20,500
Oil, Sunflowerseed	1,803	1,419	717	827
Other	2,134	2,051	2,121	2,154
Total	39,455	40,443	40,428	40,800
Imports				
Oil, Palm	6,190	4,377	3,203	4,175
Oil, Peanut	292	247	347	250
Oil, Rapeseed	1,978	2,039	2,171	2,150
Oil, Soybean	365	381	296	300
Oil, Sunflowerseed	1,555	1,207	532	600
Other	967	884	956	995
Total	11,347	9,135	7,505	8,470

Source: Foreign Agricultural Service/USDA Global Market Analysis

Table 10: India Oilseeds and Products Supply and Distribution

Thousand Metric Tons

	2022/23	2023/24	2024/25	2025/26
Production				
Oilseed, Cottonseed	11,166	10,783	10,189	10,104
Oilseed, Peanut	6,300	6,000	7,100	7,500
Oilseed, Rapeseed	11,200	11,600	11,520	12,000
Oilseed, Soybean	12,411	11,875	12,882	11,027
Oilseed, Sunflowerseed	215	112	113	113
Other	1,022	1,021	1,021	1,021
Total	42,314	41,391	42,825	41,765
Domestic Consumption				
Meal, Cottonseed	4,443	4,409	4,329	4,222
Meal, Rapeseed	4,350	4,600	4,360	4,900
Meal, Soybean	6,625	7,075	7,185	7,130
Other	2,176	2,069	2,146	2,198
Total	17,594	18,153	18,020	18,450
SME				
Meal, Cottonseed	3,600	3,573	3,508	3,421
Meal, Rapeseed	3,095	3,273	3,102	3,486
Meal, Soybean	6,225	6,625	6,710	6,700
Other	2,021	1,903	2,015	2,086
Total	14,941	15,373	15,335	15,693
Food Use Dom. Cons.				
Oil, Cottonseed	1,315	1,290	1,285	1,265
Oil, Palm	8,300	8,340	8,150	8,455
Oil, Peanut	1,050	995	1,000	1,170
Oil, Rapeseed	3,600	3,900	3,925	4,000
Oil, Soybean	5,400	5,175	6,645	6,590
Oil, Sunflowerseed	2,750	3,525	2,900	3,050
Other	400	410	395	405
Total	22,815	23,635	24,300	24,935
Domestic Consumption				
Oil, Cottonseed	1,361	1,345	1,330	1,305
Oil, Palm	8,900	8,990	8,800	9,105
Oil, Peanut	1,060	1,005	1,010	1,180
Oil, Rapeseed	3,680	3,980	4,005	4,080
Oil, Soybean	5,400	5,175	6,645	6,590
Oil, Sunflowerseed	2,750	3,525	2,900	3,050
Other	710	730	695	735
Total	23,861	24,750	25,385	26,045
Imports				
Oil, Cottonseed	1	0	1	5
Oil, Palm	10,045	8,886	7,786	9,050
Oil, Peanut	0	0	0	0
Oil, Rapeseed	6	6	26	40
Oil, Soybean	3,968	3,308	5,471	4,650
Oil, Sunflowerseed	2,988	3,516	2,905	3,050
Other	111	131	98	145
Total	17,119	15,847	16,287	16,940

Source: Foreign Agricultural Service/USDA Global Market Analysis

ENZYMATIC FATTY ACID ETHYL ESTERS SYNTHESIS USING ACID SOYBEAN OIL AND LIQUID LIPASE FORMULATION

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ABSTRACT

Acid oils represent a low-cost feedstock for biodiesel synthesis. The aim of this work was to study a single-step enzymatic esterification and transesterification process for fatty acid ethyl esters (FAEEs) production employing acid oils, ethanol, and liquid lipase formulation. The effects of lipase source (CALB, Palatase 20000L, Lipolase 100L, and Callera Trans L), temperature and enzyme ratio were studied in the transesterification of refined soybean oil with ethanol. The highest yield esters content (97%) was obtained at 30 C with 10% vol/vol of Lipolase 100L. The ethanolysis of acid soybean oil, using soybean oils with different acid contents (acid value (AV): 8.5, 50, and 90), was investigated using 10% vol/vol of lipase at 30 C. The highest esters content (71%) was obtained employing acid oil with AV 50 and Palatase 20,000L. The results showed the significant performance of soluble lipases in transesterification reactions of acid oils aiming for FAEEs synthesis.

KEYWORDS: Acid oil; esterification; ethanol; fatty acid ethyl esters; liquid formulation lipase; transesterification

Introduction

Biodiesel is a mixture of monoalkyl esters derived from long chain fatty acids, obtained from renewable sources that can be used as an alternative to diesel fuel (Atabani et al., 2014; Aghbashlo et al., 2016; Hosseinpour et al., 2016). This bio-fuel can be synthesized from the transesterification of triglycerides (TG) with short chain alcohols or esterification of fatty acids. Ethanol and methanol are used more frequently, particularly the

latter since it has a lower cost. However, methanol is more toxic, and it is specially produced from a fossil fuel derived from a nonrenewable source (Tan et al., 2010; Poppe et al., 2015). The use of ethanol in the biodiesel synthesis makes the obtained fuel completely renewable, since this alcohol is obtained in Brazil mainly by the fermentation of sugarcane (Stamenkovic et al., 2011).

The conventional process of biodiesel production is based on the transesterification of animal fat and vegetable oils that have to be refined with

alcohols employing basic catalysts as alkoxides, carbonates, potassium, or sodium hydroxides (Hama and Kondo, 2013; Guldhe et al., 2014; Cesarini et al., 2015). High yields are obtained at short reaction times. However, the negative aspects of the process are its catalyst and product recovery, wastewater treatment, and the indispensable use of refined oils, known as first generation biodiesel feedstock, which are expensive, increasing process costs (Jegannathan et al., 2010; Hama and Kondo, 2013; Christopher et al., 2014; Guldhe et al., 2014; Pedersen et al., 2014).

The use of cheaper raw materials such as animal fats, waste oils (waste cooking oil), and non-edible oils, known as a second-generation biodiesel feedstock, is a low-cost option, although it has some drawbacks as the high content of free fatty acids (FFAs). The main disadvantage of the process catalyzed by alkali is its sensibility toward FFA in oils that lead to soap formation during the transesterification process (Christopher et al., 2014).

These disadvantages can be overtaken with an alternative route based on the enzymatic biodiesel synthesis using lipases (EC 3.1.1.3, triacylglycerol

hydrolases). Those enzymes can catalyze transesterification of TG and esterification of FFAs and alcohol to biodiesel in one step (Christopher et al., 2014; Cesarini et al., 2015). This flexibility provides the synthesis of biodiesel using low-cost raw material with a high concentration of FFAs, the case of second generation biodiesel feedstock (Cesarini et al., 2013; Christopher et al., 2014; Aguiéiras et al., 2015; Cesarini et al., 2015). Besides, the process employing enzymes supports the water content present in the oil, avoiding the drawback of soap formation due to alkaline transesterification, uses lower alcohol to oil ratio, and provides easier product separation and recovery. Moreover, lipases exhibit higher stability and performance in FFA-rich substrates than in TG-rich vegetable oils (Christopher et al., 2014).

Several lipases obtained from various sources have been investigated for biodiesel synthesis (Tan et al., 2010; Christopher et al., 2014; Poppe et al., 2015). The ability of lipases to catalyze the different reactions varies between particular enzymes, and consequently, the rate of the enzyme-catalyzed reaction and its yield depend on the employed lipase (Cesarini et al., 2013; Pedersen et al., 2014). Recent researches related to the effects of the use of lipases in biodiesel synthesis have been carried employing them in the immobilized form. However, it has some drawbacks, such as low biocatalyst productivity, due to mass transfer, since it uses heterogeneous catalysts, and the high cost of enzymes, which makes this alternative still unfeasible for industries to apply (Correa et al., 2011; Hama and Kondo, 2013; Christopher et al., 2014; Aguiéiras et al., 2015).

A probable solution for those drawbacks could be the employment of the lipases in their free form, which are cheaper and act as homogeneous catalysts, allowing a faster reaction rate (Lv et al., 2010; Cesarini et al., 2013, 2014; Pedersen et al., 2014; Aguiéiras et al., 2015; Firdaus et al., 2016).

Preliminary researches indicated that lipases in their free form could be capable of efficiently catalyzing the alcoholysis of refined soybean oils for biodiesel preparation (Chen et al., 2008; Ren et al., 2011, 2013).

These non-immobilized lipases are much cheaper than the immobilized ones, and they can also be reused for several times if they are recovered from the glycerin phase in biodiesel production, making them more cost-efficient when compared to their immobilized forms (Cesarini et al., 2013, 2014). Through appropriate strategy, free lipases also can be recovered and reused with rather good operational stability remained, turning it favorable for practical applications (Chen et al., 2008; Lv et al., 2010; Ren et al., 2013).

Since the employment of acid oils and free lipases has a lack of study, this work aimed to investigate a single-step enzymatic esterification and transesterification process for fatty acid ethyl esters (FAEEs) production through reactions of acid oils with ethanol, employing liquid lipase formulation. The FAEEs reaction was carried out in a single batch reactor, and the use of free lipases would allow a single-step conversion of both FFA and TG to FAEE. The effects of temperature, enzyme concentration, and FFA content present in soybean oil were investigated. The comparison of FAEEs synthesis using the chosen soluble lipases to carry the experiments, Lipase B from *Candida antarctica* (CALB), Palatase 20,000 L, Lipolase 100 L, Callera Trans L, and their respective immobilized forms (Novozym 435, Lipozyme RM-IM, Lipozyme TL-IM, and Callera Ultra) was also described. Lipase-catalyzed esterification between oleic acid and ethanol was also studied as a model reaction to evaluate the efficiency of these free soluble lipases on FFA removal.

Material and Methods

Materials

Reactions were conducted using four distinct commercial liquid lipases: CALB (lipase B from *C. antarctica*), Palatase 20,000 L (lipase from *Rhizomucor miehei*), Lipolase 100 L (lipase from *Thermomyces lanuginosus*), and Callera Trans L (lipase from *T. lanuginosus*). Also, some reactions were conducted with their respective immobilized form: Novozym 435 (non-specific lipase from *C. antarctica* immobilized on a macroporous acrylic resin), Lipozyme

RM IM (1,3-specific lipase from *R. miehei* immobilized on an anionic resin), Lipozyme TL-IM (1,3-specific lipase from *T. lanuginosus* immobilized on a granulated silica), and Callera Ultra (1,3-specific lipase from *T. lanuginosus* immobilized). These lipases were supplied by Novozymes.

Refined soybean oil was supplied by Sadia (Rio de Janeiro, Brazil) and has the following composition in fatty acids (wt %): 0.1% lauric acid, 11.3% palmitic acid, 0.1% palmitoleic acid, 4.3% stearic acid, 25.8% oleic acid, 52.1% linoleic acid, 5.1% linolenic acid, 0.7% arachidonic acid, 0.3% behenic acid, and 0.2% linoelaidic acid.

Acid soybean oil was prepared by the addition of oleic acid to the refined soybean oil in order to obtain oil samples with acid value (AV) of 8.5, 50, and 90 (mg of KOH g⁻¹ of oil). Refined soybean oil employed presented an AV of 0.5. Ethanol 99.8% (P.A.) and *n*-hexane (99%) were obtained from Vetec Química Fina Ltda (Rio de Janeiro, Brazil). Methyl heptadecanoate (99%) was purchased from Sigma/Aldrich (St. Louis, USA). Other reactants were obtained commercially and were of analytical grade.

Esterification activity Determination

Esterification activities of the commercial liquid lipases were determined by consumption of oleic acid in the esterification reaction with ethanol (oleic acid/ethanol molar ratio of 1/1), using 10% vol/vol or 5wt % of biocatalyst at 30 °C. Esterification reactions were conducted in a sealed batch reactor. Reaction progress was monitored by sampling 100mL aliquots at various time intervals. These were dissolved in acetone/ethanol mixture (35mL), and the residual oleic acid was determined by acid–base volumetric analysis with sodium hydroxide 0.02mol L⁻¹ using a Mettler Toledo T50 Titrator.

One esterification activity unit (U) was defined as the enzyme amount that consumes 1μmol of oleic acid per minute under the experimental conditions detailed above (Correa et al., 2011).

Ethanolysis of soybean oil

FAEEs synthesis was carried out in a closed 15 mL

batch reactor magnetically stirred, coupled to a condenser in order to avoid alcohol loss. The temperature was kept constant by circulation of ethylene glycol in the reactor jacket.

The reaction mixture consisted of soybean oil, ethanol, and liquid lipase. Soybean oil mass used was 8 g. This oil mass corresponds at 0.01 mol of TG and is based on the molar mass of oil, calculated from the oil composition (801 g mol⁻¹). Total ethanol loading was determined with respect to its molar ratio with reactants. The ethanol volume was added in three stages (1/3 per stage) at the reaction time of 0 h, 0.5 h, and 1 h according to the work by Bernardes et al. (2007). The stepwise addition of ethanol was used to prevent enzyme inhibition. Reaction progress was monitored by taking samples, in duplicate; at fixed intervals that were analyzed for unreacted oleic acid and ethyl ester content (FAEE).

To determine the content of ethyl esters and consumption of oleic acid in the samples of FAEEs synthesis reactions, a chromatographic method adapted from the standard indicated by the European Standardization Committee (Draft prEN 14103, 2001) was applied.

To calculate the obtained content of ethyl esters in each reaction we have followed the criterion indicated by the standard. The sum of the areas of the esters in the sample (previously weighted) is compared to the area of a known mass of standard, within the linear range of the detector for methyl heptadecanoate (standard) and the mass percentage content of the esters obtained in the reaction (biodiesel) is calculated (Equation (1)).

$$C = \frac{(\sum A) - A_{PI}}{A_{PI}} \times \frac{C_{PI} \times V_{PI}}{M_{am}} \times 100 \quad (1)$$

C = percentage content of esters (biodiesel)

$\sum A$ = total area of the peaks of esters;

A_{PI} = peak area of the internal standard;

C_{PI} = concentration of methyl heptadecanoate standard in hexane (mg mL⁻¹);

V_{PI} = volume of the internal standard solution used to dissolve the sample (mL);

M_{am} = sample mass (mg).

Effect of temperature

The effect of temperature (30 °C, 40 °C, and 50 °C) was studied in the reactions carried out with the stoichiometric molar ratio of ethanol:oil (3:1), and 1000 U of the commercial liquid lipases.

Effect of enzyme concentration

The enzyme concentration (0.5, 1, 2, 5, 7, 10, and 13% vol/vol) was investigated in the ethanolysis of soybean oil (molar ratio of oil:alcohol equal to 1:3) at 30 °C using Palatase 20,000 L, Lipolase 100 L, CALB, or Callera Trans L.

Effect of acid content

The effect of acid content on soybean oil (AV of 0.5, 8.5; 50 and 90) was investigated in the reactions carried out at 30 °C, using stoichiometric alcohol amounts with respect to both reactants (ethanol/oil molar ratio = 3/1 and ethanol/oleic acid = 1/1), and 10% vol/vol of lipase (CALB, Palatase 20,000 L, Lipolase 100 L, and Callera Trans L).

Ethyl oleate synthesis

Ethyl oleate synthesis was carried out in a closed 15-mL batch reactor magnetically stirred, coupled to a condenser in order to avoid alcohol loss. The temperature was kept constant by circulation of ethylene glycol in the reactor jacket. The progress of the reaction was verified by taking samples, in duplicate; at fixed intervals that were analyzed by acid–base volumetric analysis for unreacted oleic acid.

Effect of temperature

The effect of temperature on esterification of oleic acid with ethanol was studied at 30, 40, 50, and 60 °C using the stoichiometric ratio of the reagents and 10% vol/vol of lipase (CALB, Palatase 20,000 L, Lipolase 100 L, and Callera Trans L).

Effect of enzyme concentration

Esterification reactions were carried out at 30 °C using 0.5, 1, 2, 5, 10, 20, and 30% vol/vol of lipase.

Gas chromatographic analysis

The gas chromatographic analysis of FAEEs and oleic acid was made using VARIAN CP 3380 equipment with a flame ionization detector (FID), and a capillary column CP WAX 52 CB (30 m × 0.25 mm × 0.25 µm), employing a split injection system in the ratio of 1:20. The injector and the detector temperatures were kept at 280 °C and 300 °C, respectively. The oven was first maintained at 200 °C for 4.5 min, then heated up to 250 °C at a 20 °C min⁻¹ rate and kept constant at the final temperature for 5 min. Hydrogen was employed as carrier gas at the rate of 2 mL min⁻¹. Methyl hepta-decanoate was used as internal standard. The ethyl ester content was calculated as grams of ethyl esters produced per grams of sample.

Acid–base volumetric analysis

Esterification progress was monitored from the quantification of the oleic acid contained in the reaction medium by acid-base volumetric analysis, taking duplicate samples during all the reaction time. Aliquots of 50 µL were withdrawn using an automatic pipette and immediately added to a mixture of acetone/ethanol (1/1). The oleic acid content in the samples was determined by titration employing NaOH 0.02 mol L⁻¹ using automatic titrator Mettler Toledo T50. The conversion was defined as the number of moles of oleic acid reacted per mole of oleic acid fed to the system.

Results and Discussion

Esterification activity

The esterification activities of CALB, Palatase 20,000 L, Lipolase 100 L, and Callera Trans L were determined and the obtained results were 371, 600, 370, and 261 U mL⁻¹, respectively. These results show that Palatase 20,000 L has excellent catalytic potential in esterification reactions at 30 °C, especially when compared to CALB, Lipolase 100 L, and Callera Trans L. The esterification activities of their respective immobilized forms were 1950; 1945; 725; and 2400 U g⁻¹ for Novozym 435, Lipozyme RM-IM, Lipozyme TL-IM, and Callera Ultra, respectively. The

performances of lipases in support were better than that obtained with free lipases.

Ethanolysis of soybean oil

Effect of temperature

The production of FAEE employing enzymes is usually performed in the temperature range between 30 and 55°C, in order to prevent loss of lipases activity (Gog et al., 2012; Christopher et al., 2014). Lipases from different sources show optimum temperatures in the range of 20 °C–70 °C for their activity. In this study, the chosen range of temperatures for transesterification reactions was 30 °C–50 °C. The molar ratio of alcohol/soybean oil was equal to 3 (stoichiometric molar ratio) in all of the experiments according to preliminary results of the group (Bernardes et al., 2007).

The results obtained with Palatase 20,000 L, Lipolase 100 L, and Callera Trans L are presented in Figure 1. For Palatase 20,000 L (Figure 1(a)), it can be seen that increasing the temperature decreased the FAEEs yield. After 4 h of reaction, the achieved FAEE yields were 46%, 43%, and 35% at 30 °C, 40 °C, and 50 °C, respectively.

In reactions with Callera, as the temperature was increased, FAEEs yield was significantly decreased (Figure 1(b)). After 4 h, the FAEE yields obtained were 53%, 36%, and 13% at 30 °C, 40 °C, and 50 °C, respectively.

Also, reactions with Lipolase 100 L (Figure 1(c)) showed the same performance with a decrease in FAEE yields while increasing the temperature. After 4 h of reaction, the FAEE yields achieved were 84.6%, 67.8%, and 51.4%, at 30 °C, 40 °C, and 50 °C, respectively.

The FAEEs yield obtained using CALB was lower than 2% in all temperatures tested.

The effect of temperature on transesterification reaction with immobilized lipases had been already investigated by our group (Pedro et al., 2018). With Novozym 435, FAEE yield increased as temperature was increased until 70 °C, of which 62% was obtained. In reactions with Lipozyme RM IM and Lipozyme TL IM, the FAEEs concentration was increased until 50 °C,

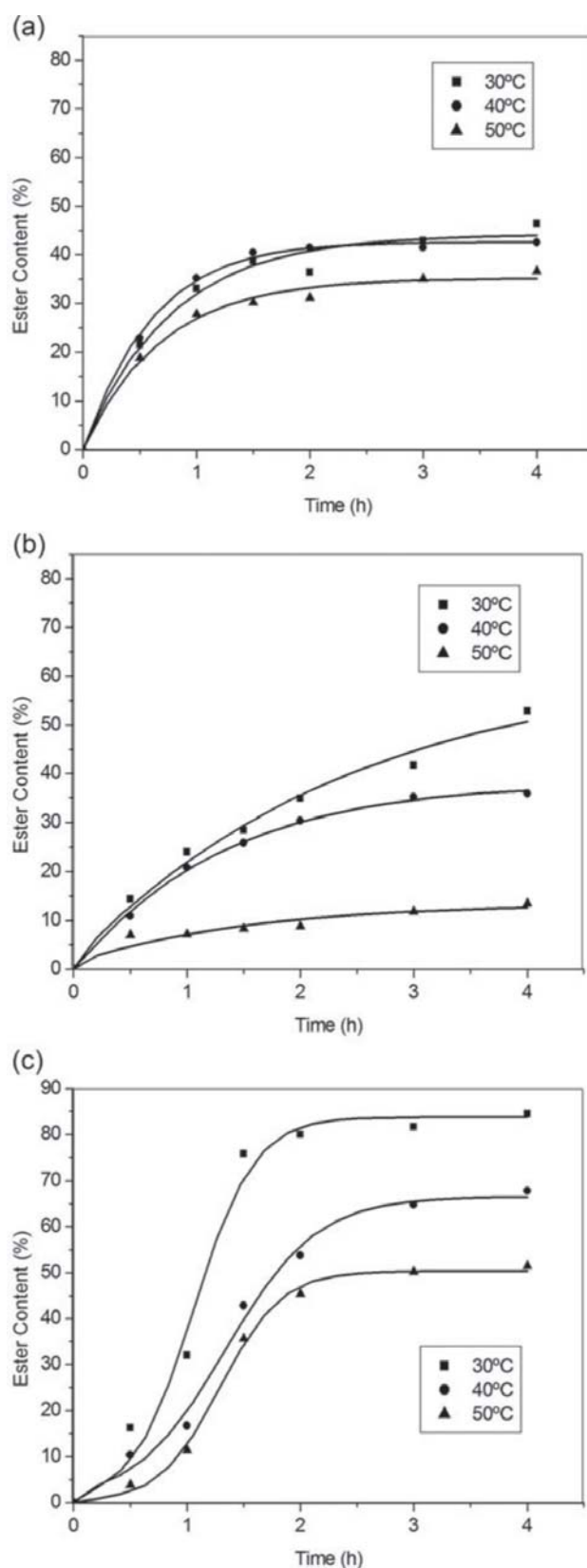


Figure 2. Ester content (wt %) during 4 h of transesterification reaction between refined soybean oil (AV 0.5) and ethanol at 30 °C using different lipase concentrations (% vol/vol). (a) Palatase, (b) Callera Trans, (c) Lipolase 100 L.

decreasing slightly for temperatures higher than 60 °C. The highest yield obtained for Lipozyme RM IM and Lipozyme TL IM were 32% and 52%, respectively, at 50 °C. For Callera Ultra, the optimum temperature was also determined at 70 °C, obtaining a yield of 60% after 4 h.

The differences among these commercial lipases can be justified by analyzing the susceptibility of the enzyme to denaturation at elevated temperatures, which can vary according to many factors (pH, solvent, substrates, products, etc.) and can be distinguished from one protein to another. Compared to their respective free forms, immobilized lipases exhibited higher optimum temperatures, even differing from one another. Generally, immobilized lipases show a higher resistance to temperature when compared to free ones (Fjerbaek et al., 2009). The binding of the carrier material gives stability to the enzyme and promotes a decrease of the thermal effect, reducing the deactivation when compared to the free enzyme (Fjerbaek et al., 2009). The most intriguing result, however, was obtained when comparing CALB to its immobilized lipase, Novozym

435. CALB did not present any significant result for any temperature – the highest yield obtained was 2% at 30 °C – even though Novozym 435 showed the highest yield of all in its optimum temperature (70 °C), proving that this enzyme has excellent catalytic potential for transesterification, unlike its free form.

Effect of enzyme concentration

Reactions with 0.5%, 1%, 2%, 5%, 7%, 10%, and 13% of Palatase 20,000 L were carried out to investigate its effect in the FAEs yield. After 4 h, the reaction carried out with 10% vol/vol of enzyme presented the highest FAEE yield (46%). Reactions with 5% obtained a FAEE yield of 31%. However, the reactions with less than 5% of enzyme were not able to reach 1% of FAEE yield, and these results were not considered in this study. Results are presented in Figure 2.

After determining that the highest FAEs yield with Palatase 20,000 L was obtained when employing 10% vol/vol of lipase (Figure 2(a)), the same enzyme concentrations of 0.5, 1%, 2%, 5%, 7%, 10%, and

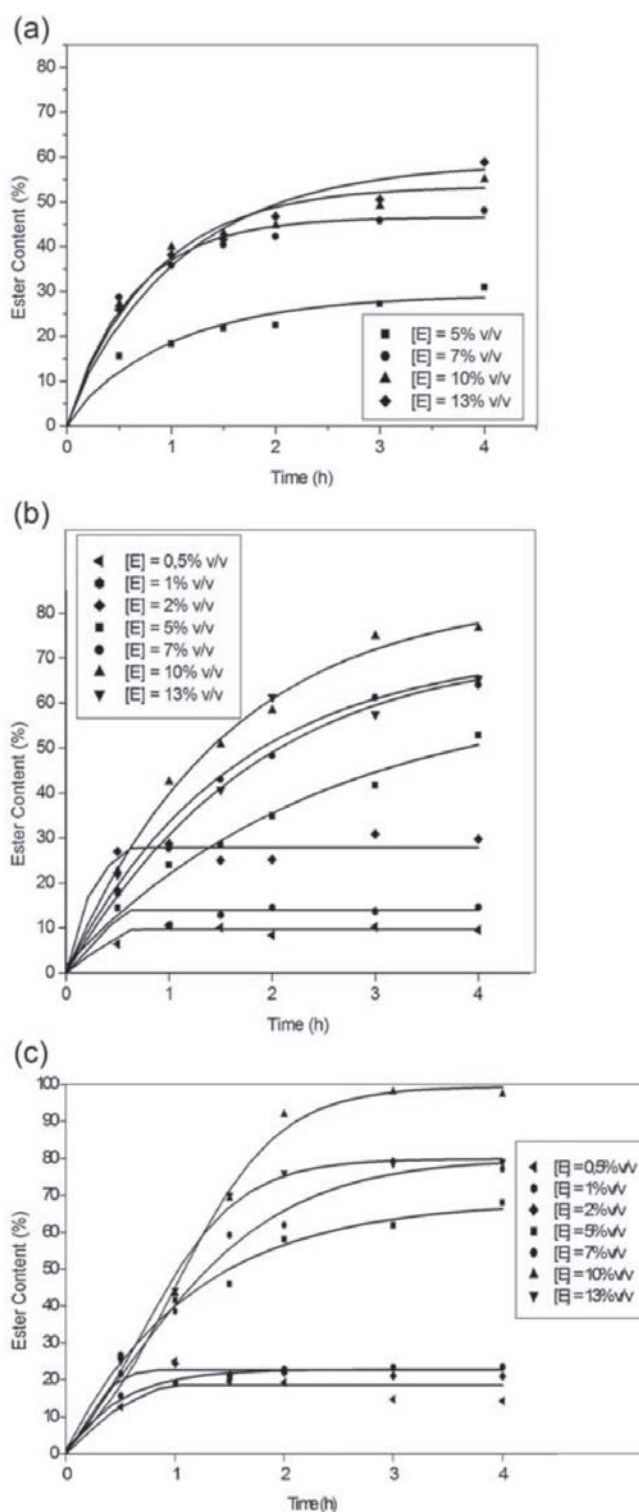


Figure 2. Ester content (wt %) during 4 h of transesterification reaction between refined soybean oil (AV 0.5) and ethanol at 30 °C using different lipase concentrations (% vol/vol). (a) Palatase, (b) Callera Trans, (c) Lipolase 100 L.

13% were applied for Callera Trans L (Figure 2(b)) and Lipolase 100 L (Figure 2(c)). Again, CALB was

not able to present significant results, and so its results will be not shown.

Analyzing the results obtained with Callera Trans L, the enzyme concentration of 10% vol/ vol was again the one that presented the highest FAEE yield (77%). FAEE concentrations of 53%, 64%, and 65% were obtained with 5, 7, and 13% vol/vol, respectively. Among the studied lipases, Callera was the only enzyme preparation to pre-sent considerable yields with less than 5% vol/vol of enzyme concentration (30%, 15%, and 10% with 2, 1, and 0.5% vol/vol, respectively).

Evaluating the results obtained for Lipolase 100 L, the concentration that made it possible to reach the highest conversion (97.3%) was 10% vol/vol. The FAEE yields for the contents 0.5, 1, 2, 5, 7, and 13% vol/vol were of 14.2%, 23.4%, 20.9%, 68%, 77.2%, and 79.1%, respectively.

The decrease in the obtained FAEEs yield when increasing enzyme concentration above 10% vol/ vol for the lipases Palatase 20,000 L, Lipolase 100 L, and Callera Ultra can be justified by the nature of liquid lipase formulations, which are aqueous solu-tions, and by increasing their volume in the reac-tion medium, the water content increases as well. Presence of water in the reaction mixture can pro-mote hydrolysis of esters, and therefore the decrease in the esters content and an increase in FFA (Guldhe et al., 2014). The biodiesel synthesis employing lipases is conducted in mostly non-aqueous medium, as water plays multiple roles and it has a substantial influence on the catalytic activ-ity and stability of the lipase (Tan et al., 2010). Different from most immobilized lipases, quite a significant amount of water was necessary for transesterification reaction mediated by soluble lipase (Cesarini et al., 2014). The water content in the reaction medium has some benefits like the dilution of ethanol and the formation of a second liquid phase, producing an interface that is respon-sible for activating many lipases (Tan et al., 2010; Pedersen et al., 2014).

The influence of water on biodiesel synthesis using 0.5% of Callera Trans L was studied by Pedersen et al. (2014). The rate of conversion during the initial stage of the reaction increases considerably when the water

content is increased from 5% to 10%, with a small marginal improve-ment by going to 20% and 30%. The optimum water content is likely to be dependent upon mixing conditions, ethanol concentration, and the ethanol addition scheme.

When employing Callera Trans L in biodiesel synthesis, its reaction rate is indirectly proportional to the enzyme concentration, suggesting that a sat-uration level is obtained (Firdaus et al., 2016). This behavior can be expected for systems with two phases, one for the catalyst and the other for the substrate, interacting only at the interface.

Also, with more enzyme, the reaction would become limited by the maximum adsorptive cap-acity of the interface, meaning that the interfacial area is too small to allow for all the enzyme to absorb onto effectively (Pedersen et al., 2014), what would also decrease the catalytic potential of higher enzyme concentrations. The results obtained in these experiments confirm this behavior.

The effect of enzyme concentration on FAEEs synthesis was studied for immobilized lipases at 50 °C. Lipozyme RM IM gave the highest FAEE yield (51%), after 4 h when employing 7 wt % of the enzyme, which was similar to that obtained with 9 wt % of the enzyme. Novozym 435 pre-sented ever-increasing FAEE yields until 9 wt % of the enzyme, which was the highest concentra-tion employed (73%). Callera Ultra also showed its best performance with 9 wt % of the enzyme, obtaining a yield of 89% at 70 °C.

Comparing free lipases to their respective immobilized forms, Novozym 435 and CALB again presented the most different results. Novozym 435 presented a yield of 73% with 9 wt % while CALB was not able to present good results in any concentration, asserting that this enzyme is not proper to transesterification reac-tions when in its free form.

Palatase 20,000 L and Callera Trans L showed similar results to their respective immobilized forms (Lipozyme RM IM and Callera Ultra). All of them presented their better results when around 10% of enzyme concentration and the highest yields with immobilized

lipases were slightly higher than that obtained with their free forms, indicating once more that the employment of free lipases does not lose efficiency in transesterification reactions.

Lipozyme TL IM presented its best FAEEs yields (50%) when employing 5 and 7% wt of the enzyme. With higher concentrations, the yield has declined. For Lipolase 100 L the best result was achieved employing 10% vol/vol of lipase.

Ethyl oleate synthesis

Lipases are enzymes that can catalyze both esterification and transesterification reactions in non-aqueous medium. So, these enzymes can be employed in the biodiesel production using acid oils, which are cheaper than refined ones, as a way to decrease the FFA content and to favor the transesterification reaction. Lipase-catalyzed esterification between oleic acid and ethanol was defined with standard reaction to evaluate the efficiency of these biocatalysts on FFA removal because oleic acid is one of the predominant fatty acids in the vegetable oils used for biodiesel synthesis (soybean oil, palm oil, etc.) and is liquid at ambient temperature. The influence of temperature and enzyme concentration in esterification of oleic acid with ethanol using liquid commercial lipase was studied. Preliminary studies to evaluate the influence of the amount of ethanol in the conversion obtained with esterification reactions catalyzed by liquid commercial lipases varying the amount of ethanol (ethanol/oleic acid molar ratios equal 1 and 2, and their addition form (single, stepwise, and continuous) had been done. The preliminary results showed there was no significant conversion difference when the ethanol addition was performed in a single step using the stoichiometric ratio of the reactants. The use of ethanol/oleic acid molar equal to 2 did not promote a significant increase in the conversion. Therefore, the experiments were carried out with the stoichiometric molar ratio of reagents (ethanol/oleic acid molar ratio = 1).

Effect of temperature

Esterification reactions between oleic acid and ethanol were carried out for the four free lipases studied in this work (CALB, Palatase 20,000 L, Lipolase 100 L, and

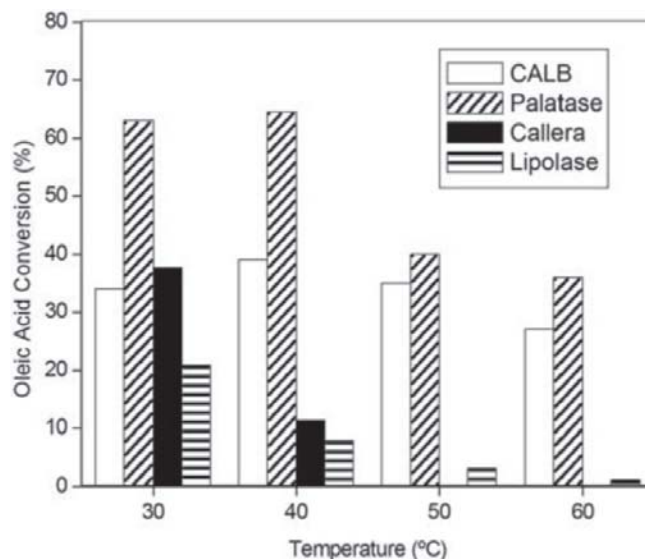


Figure 3. Oleic acid conversion (%) in esterification with ethanol after 30 min of reaction, using 10% vol/vol of lipase liquid formulation (CALB, Palatase 20000 L, Lipolase 100 L, and Callera Trans L) at 30 °C, 40 °C, 50 °C, and 60 °C. Molar ratio of oleic acid:ethanol = 1.

Callera Trans L), employing 10% vol/vol of each, at 30 °C, 40 °C, 50 °C, and 60 °C for 30 min. The results of these reactions are presented in Figure 3.

Lipolase 100 L and Callera Trans L have all presented an optimum temperature of 30 °C for transesterification reactions. When studying the effect of temperature for esterification activity, Callera was only able to present good results at 30 °C (38%). At 40 °C, it showed a lower conversion (11%), and for higher temperatures, no oleic acid was converted to an ester. The increase in the reaction temperature in esterification reactions with Lipolase 100 L lipase caused a decrease in conversion. The ethyl oleate values obtained at the temperature of 30 °C, 40 °C, 50 °C, and 60 °C were 20.8%, 7.9%, 3.2%, and 1.1%, respectively.

Even though Palatase could convert oleic acid at 50 °C and 60 °C, the results at these temperatures were not as good as the ones with 30 °C and 40 °C, which were very similar (63% and 64.5%, respectively), exactly like the results shown in section “Ethanolysis of soybean oil” for transesterification reactions. Both temperatures could be used for carrying reactions with this enzyme.

As predicted, CALB presented a good performance for esterification, entirely different from the

transesterification activity. Its highest conversion was obtained at 40 °C (39%), but this enzyme was able to convert enough oleic acid at 30 °C and 50 °C as well (34% and 35%, respectively). A considerable reduction in conversion using CALB was noted only at 60 °C.

Effect of enzyme concentration

Esterification reactions between oleic acid and ethanol were carried out for the four free lipases studied in this work (CALB, Palatase 20,000 L, Lipolase 100 L, and Callera Trans L), employing 0.5, 1, 2, 5, 10, 20, and 30% vol/vol of each, at 30 °C for 30 min. The results of these reactions are presented in Figure 4.

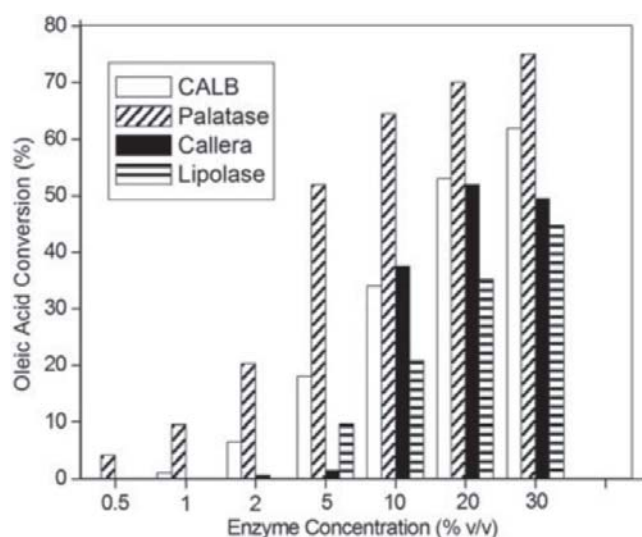


Figure 4. Oleic acid conversion (%) in esterification with ethanol after 30 min of reaction, using 0.5, 1, 2, 5, 10, 20, and 30% vol/vol of lipase liquid formulation (CALB, Palatase 20000 L Lipolase 100 L, and Callera Trans L) at 30 °C. Molar ratio of oleic acid:ethanol = 1.

Again, CALB presented great results if compared to its transesterification performance, achieving conversions of 18%, 34%, 53%, and 62% with 5, 10, 20, and 30% vol/vol of the enzyme, respectively. This ever-increasing behavior is somehow surprising since more enzyme leads to a saturation level, which was not obtained in this case.

Lipolase 100 L showed good results in the esterification of oleic acid, as the conversion increased with the increment of the enzyme, reaching conversions of 9.6%, 20.8%, 35.2%, and 44.8% for the contents of 5, 10, 20, and 30% vol/vol.

Palatase 20,000 L was responsible for higher conversions than CALB (75% with 30% vol/vol of enzyme) but had a similar performance. The conversions were increasing as the concentration of the enzyme was also increasing. Compared to this enzyme's transesterification activity, it is not-able that this enzyme acts different in these reactions since it has found its optimum concentration at 10% vol/vol for transesterification, already decreasing with 13% vol/vol and here, it has continuously increased until 30% vol/vol. It is important to state that experiments with higher concentrations were not carried out because it would have been a lot of enzymes, which would lead to a higher cost for the process.

Unlike the others, Callera Trans L has only increased its conversions to 20% vol/vol (52%). When employing 30% vol/vol of this enzyme, the conversion has decreased to 49.5%. However, that concentration is still higher than the optimum for transesterification reactions, which was 10%

Effect of acid content on soybean oil

The effect of acid content (AVs of 8.5, 52, and 90) on soybean oil was investigated in biodiesel synthesis using liquid lipase formulations (CALB, Palatase 20,000 L, Lipolase 100 L, and Callera Trans L). Also, transesterification reactions with pure soybean oil (AV 0.5) were carried out. Even though the optimum conditions for CALB could not be determined for transesterification reactions, biodiesel synthesis from acid oils was carried out employing this lipase in the same conditions of the other free lipases (30 °C, 10% vol/vol of lipase).

The results presented in Figure 5 indicated once again that the catalytic potentials of Palatase 20,000 L and Callera Trans L are higher than CALB's since the reactions with those enzymes presented higher biodiesel yield for all the employed oils. The highest yield (71%) for Palatase 20,000 L was obtained with the acid oil AV 50 after 4 h. For CALB, the highest biodiesel yield was 32% with acid oil AV 90. Callera Trans L had the best result when employed with the refined soybean oil (77%). With CALB and Palatase 20,000 L, reactions with refined soybean oil (AV 0.5) presented biodiesel yields of 1.9% and 44%, respectively.

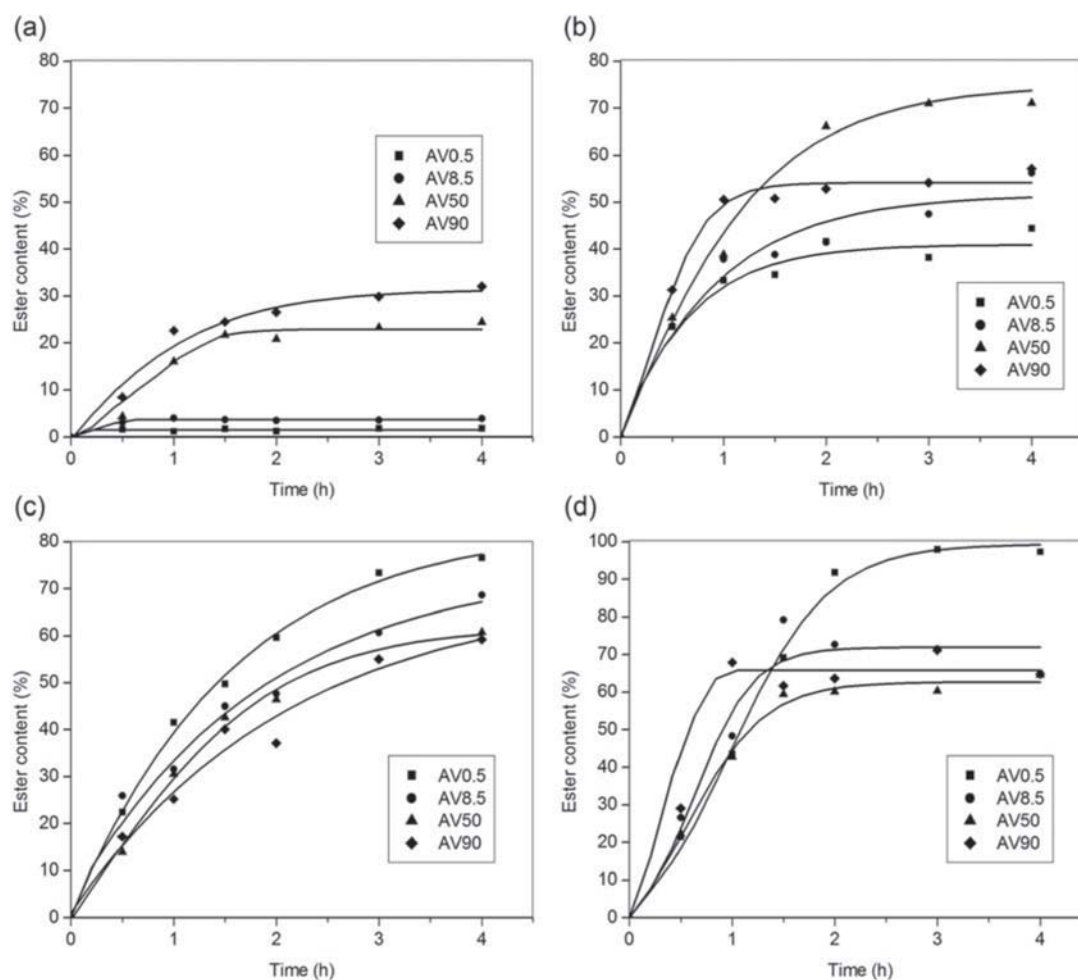


Figure 5. Ester content (wt %) in the transesterification reaction using acid soybean oil (AVs of 0.5, 8.5, 50, 90) during 4 h. (a) CALB, (b) Palatase, (c) Callera Trans, (d) Lipolase 100 L.

Reactions with CALB showed that biodiesel yield increased when the acidity of oil was higher, as presented in Figure 5(a). Since this lipase showed better application for esterification than transesterification, the obtained results reflect that fact, with almost all the produced FAEs coming from the esterification reaction of the oleic acid. Novozym 435 presented high FAEs yields even with high concentrations of alcohol, the condition of reactions with acid oils of high AVs.

For Palatase 20,000 L, the observed behavior is different from that obtained with CALB, with biodiesel yield increasing as the AV of the oil was increasing until the acid oil AV 50, with which the highest biodiesel yield was obtained. FAEs yield decreased when employing acid oil AV 90 (57%). This result can be explained by the higher concentration of ethanol in reaction medium

when the acid oil AV 90 was employed, what might be responsible for decreasing the activity of Palatase 20,000 L in the reaction and, therefore, the FAEs content. Also, the high FAEs yields obtained indicate that this lipase presents significant potential for its application in transesterification reactions of acid oils. This lipase's performance can be checked in Figure 5(b).

Callera Trans L presented interesting results, showing high FAEs yields with all acid oils employed. However, the highest one among them was obtained in the reaction with refined soybean oil (AV 0.5), and while the AV was increasing, FAEs yield has decreased, as it is shown in Figure 5(c). It can be explained considering that with high AVs, more alcohol is added to the reaction medium and this high volume of ethanol might cause

denaturation of lipase, diminishing its activity in the catalysis of esterification and

transesterification reactions. Furthermore, it must be considered that the esterification reaction has as byproduct water that may negatively influence the performance of the biocatalyst and the equilibrium shift.

Lipolase 100 L presented FAEE yields in the range of 65% for oils with AVs of 8.5, 52, and 90 (Figure 5(d)). The best result (97.3%) was obtained using refined soybean oil (AV 0.5). These results indicated that this lipase can be employed in the synthesis of FAEEs with acid oils.

Cesarini et al. (2013) reported that in an aqueous medium, the conversion of soybean oil into FAMES catalyzed by Callera Trans L presented the way this enzyme operates, with a first hydrolysis step. Only after that step, the esterification of the fatty acids with methanol starts. In the first 5 h, the release of FAMES comes from the transesterification activity of the enzyme. At longer reaction times, after almost all the glycerides have disappeared, esterification activity takes place using the fatty acids originated by the hydrolysis of TG, diglycerides, and monoglycerides. This behavior was also reported by Lv et al. (2010), in the methanolysis reaction with NS81006, a soluble lipase, all the glycerides were hydrolyzed, generating fatty acids, which were transformed into esters by the following esterification.

These results indicate that Palatase 20,000 L and Lipolase 100 L not only have a great catalytic potential for esterification reactions, but also for transesterification reactions. Since its highest FAEE yield was obtained in a reaction in which the FAEE comes almost exclusively from transesterification, Callera Trans L is very efficient for this kind of reaction even though it can be nicely employed for esterification. In contrast, FAEEs yields obtained with CALB indicate that this lipase presents a better performance in esterification reactions than transesterification ones.

When compared to their immobilized counterparts, Palatase 20,000 L and Lipolase 100 L were able to present better results than Lipozyme RM IM, and Lipozyme TL IM did. While the free lipase Palatase

20,000 L obtained its best result with acid oil AV 50 (71%), the immobilized lipase could only achieve a yield around 30% for all the employed oils, including the refined soybean one, at 50 °C. For Lipolase 100 L the best result was achieved employing refined soybean oil with acid oil AV 0.5 (97.3%). The results indicated that increasing the AV of the oil applied does not affect its performance since the FAEE yield remained close to 65% with the other acid oils employed in this study. For Lipozyme TL IM, which is the immobilized form of the enzyme, the highest FAEE yield was 50% when refined soybean oil was used, with the yield decreasing with the increase of the AV of the oil.

CALB and Novozym 435 exhibited a similar action, increasing their yields while the acid content was also increasing. However, the immobilized one had much better results with soybean oil AV 0.5 (28%) and acid oil AV 8.5 (33%) than CALB, which could not produce a yield higher than 5% in both cases. Callera Trans L had a better yield than Callera Ultra with the refined soybean oil AV 0.5 (77% and 59%, respectively), which was the best oil with both enzymes, ensuring Callera's preference for transesterification reactions again.

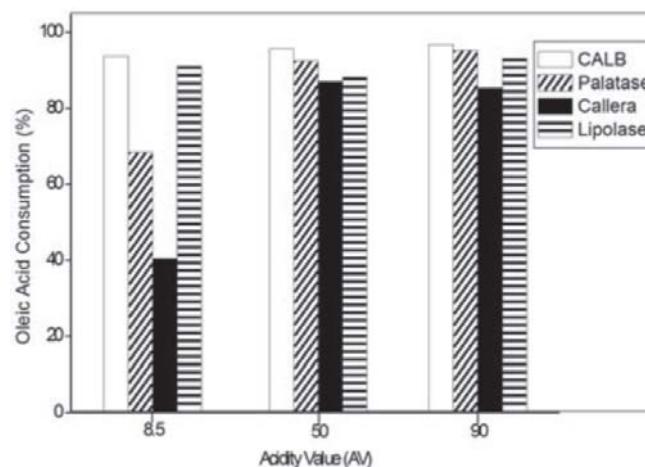


Figure 6. Oleic acid conversion obtained in transesterification reactions of acid oil (AVs 8.5, 50, and 90), using commercial lipase with lipase (CALB, Palatase 20000 L, Lipolase 100 L, and Callera Trans L) after 4 h. Reaction conditions: 10% vol/vol of lipase, ethanol/soybean oil molar ratio of 3, oleic acid:ethanol molar ratio of 1, ethanol added in three steps (1/3 at 0 h, 1/3 after 0.5 h, and 1/3 after 1 h), at 30 °C.

Oleic acid conversions were also determined in those reactions with the results being presented in Figure 6.

The obtained results indicate again that even though CALB has presented small FAEs yields, this lipase could be applied for esterification reactions of high FFA feedstock since it has converted almost all the oleic acid present in the reaction medium for all the acid oils tested.

For reactions with Palatase 20,000 L, the obtained conversions were high for acid oils with AV 50 and 90, which were 93% and 95%, respectively. When employing the acid oil AV 8.5, the obtained conversion was lower, around 70%. Lipolase 100 L presented high conversions for acid oils with AV 8.5, 50, and 90, which were 91%, 88%, and 93%, respectively. Among the employed lipases, Callera Trans L obtained the lowest FFA conversion, ensuring once again that this lipase has a lower catalytic potential for esterification than the others. Despite this fact, it was also able to present high oleic acid conversion with acid oils AV 50 and AV 90, around 90%. With acid oil AV 8.5, however, only 40% of the oleic acid present in the reaction medium was consumed after 4 h, the smallest performance shown in the experiments that were carried out in this study. Perhaps it would be necessary longer reaction time to reach higher FFA conversion.

Conclusions

Aiming to investigate the performance of four liquid lipase formulations (CALB, Palatase 20,000 L, Callera Trans L, and Lipolase 100 L) on a single-step enzymatic esterification and transesterification process for FAEs production, this paper was able to present satisfactory results. In the carried experiments, lipase Palatase 20,000 L presented the highest esterification activity (600 U mL^{-1}) among the tested enzymes.

When evaluating the effect of temperature on transesterification reactions, carrying them at the temperature of 30°C provided the highest obtained yields in FAEs employing liquid commercial lipases Palatase 20,000 L, Lipolase 100 L, and Callera Trans L. By increasing the enzyme content above 10% vol/vol, a decrease in the yield of FAEs was noted for the same group of lipases. However, lipase CALB was not able to provide great results on any of the transesterification reactions.

The best temperature for esterification reactions employing lipases CALB and Palatase 20,000 L was 40°C , obtaining conversions of 39% and 64.5%, respectively. For liquid enzyme preparations, the optimum temperature for Callera Trans L and Lipolase 100 L was 30°C and the obtained conversions were respectively 38% and 20.8%.

Palatase 20,000 L and Lipolase 100 L presented great catalytic potential not only for esterification reactions but also for transesterification reactions. The highest yield (71%) for Palatase 20,000 L was obtained employing the acid oil AV 50, while for Lipolase 100 L the best result (97.3%) was obtained using refined soybean oil (AV 0.5).

Callera Trans L proved to be very efficient for transesterification reactions, achieving its best result with the refined soybean oil (77%). CALB presented a better performance on esterification reactions than on transesterification ones. The highest biodiesel yield obtained with it was 32% employing acid oil AV 90.

The obtained results open up the possibility of employing commercial liquid lipases and acid

oils, together, presenting an alternative route using a raw material with an affordable price and lower cost catalysts that can obtain a more economical and eco-friendly process in the field of FAEs production. Also, they might be used in the pretreatment of oils with high AVs, making the oils appropriate for the conventional alkaline process. Those facts justify why the employment of those enzymes that are environmentally-friendly biocatalysts is being severally investigated and its applications in the chemist industry are increasing day by day.

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HEALTH NEWS

Plant-based omega-3s offer similar benefits to marine-derived iterations

Ahiflower oil-derived SDA is converted into EPA in the body, offering similar joint, brain and gut benefits to traditional fish oil.

A new review published in *Lipids* has highlighted the potential of plant-based omega-3 oils in promoting gut health.¹ The article delves into how omega-3 oils rich in stearidonic acid (SDA) can influence the microbiome, promote optimal gut barrier function, help mitigate systemic inflammation and boost overall wellness.

Published by researchers from the University of Southampton, the piece also explores the rising interest in plant-based omega-3 sources.

According to Baker et al., this trend is primarily driven by the increased intrigue towards both ethical and sustainable dietary choices — with many now turning away from fish oil products in favour of more environmentally-friendly options.

The review covers:

- How very long chain polyunsaturated fatty acids (VLF-PUFAs) present in plant-based extracts can balance the gut microbiome
- How VLF-PUFAs exhibit a prebiotic effect within the gut
- The potential of SDA-rich oils in mitigating inflammation as well as promoting gut barrier and immune function
- How SDA oils modulate the gut-brain/gut-liver axes
- How users can gain similar omega-3-related health and wellness benefits from plant-based sources compared with traditional fish oil
- Why plant-based omega-3s are more sustainable than traditional fish oils

Notably, the researchers tout the benefits of Nature Crops International's branded Ahiflower oil, which is

derived from *Buglossoides arvensis*.

Oil from this particular botanical species is rich in SDA, which promotes efficient omega-3 EPA conversion and DHA formation in the liver and brain; despite its inability to raise DHA levels in the red blood cells.

This suggests that the beneficial fatty acids produces are being metabolised and used by the body more efficiently, according to Baker.

“As we uncover the power of omega-3s in promoting cardiovascular, gut, skin, immune-inflammatory and mental health, there will continue to be an increase in demand for these products — creating an unsustainable supply chain if we were to rely solely on marine sources,” she says.

“To overcome this issue, it's crucial to embrace plant-based omega-3 options — which are demonstrably beneficial for all these health goals.”

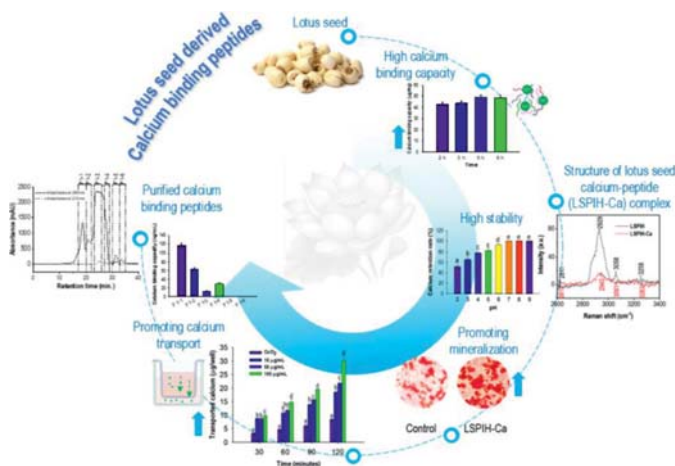
“Ahiflower oil is one of nature's richest sources of omega-3, and this newly published research only further underscores its key role in overall wellness. By choosing a clean-label, regeneratively farmed omega-3 solution, supplement manufacturers can not only enhance the benefits of their product, but also choose a sustainable option,” Baker concludes.

Source: Nutraceutical Business Review

Lotus seed (*Nelumbo nucifera*) protein-derived calcium-binding peptides: Isolation, characterization, and osteogenic effect

Introduction

Calcium deficiency, continues to be a prevalent concern, particularly among older adults and postmenopausal women. A lack of calcium can result in several diseases, such as rickets in children and osteoporosis in older adults [1]. This deficit is generally attributed to inadequate calcium consumption and limited bioavailability. Therefore, creating dependable calcium



supplements is essential to mitigate and avert future shortages. Various calcium supplements, such as amino acid chelates, organic acids, and inorganic forms have been widely studied for addressing calcium deficiency [2]. Inorganic types like CaCl_2 and CaCO_3 have low bioavailability due to intestinal precipitation [3], while organic forms such as calcium lactate are better absorbed but have lower calcium content and require adequate vitamin D. Though generally well-tolerated, supplements like calcium carbonate can cause digestive side effects [4]. Conversely, amino acid-chelated calcium improves absorption but is costly and prone to oxidation [5]. These limitations emphasize the need for cost-effective, stable alternatives like calcium-binding peptides.

Recently, bioactive peptides derived from natural dietary proteins have attracted significant attention as efficient calcium-binding agents due to their biological compatibility, including enhanced bioavailability and improved intestinal absorption [6]. Alongside these findings, recent studies have also explored innovative strategies for improving bone regeneration such as using bioactive materials and immunomodulatory scaffolds that synergize with the body's natural repair mechanisms [7]. While calcium-binding peptides derived from dietary proteins exhibited considerable promise in enhancing bone health by stimulating osteogenesis, the formation of new bone tissue, mineralization, and aiding the transport of calcium through the intestinal epithelium in both *in vitro* and *in vivo* studies. The majority of research on calcium-binding peptides has concentrated on animal or specific plant sources, including antarctic krill protein,

bovine bone collagen, and peanut [6,8,9]. This has prompted researchers to investigate more animal and plant-derived sources for calcium-binding peptides, in accordance with the increasing demand for sustainable solutions in supplements and functional meals.

Lotus (*N. nucifera* G.) is also known as water lily and Kamala. It is a freshwater annual flower belonging to the genus *Nelumbo*, which includes the species *N. nucifera* [10]. As a significant economic crop in China, it produces 45,000 tons of lotus seeds and 9 million metric tons of freshly harvested rhizomes [11]. The scientific community has demonstrated a growing interest in the sacred lotus due to its importance in gardening, medicinal use, and botanical phylogeny [10]. Recently, bone health-benefits of lotus ingredients such as polysaccharides and alkaloids have been reported [[12], [13], [14]]. Although plant-derived calcium-binding peptides are known, the specific capacity of lotus seed protein to form bioactive calcium-peptide complexes, and their combined osteogenic and bioavailability benefits, have not been characterized. The objective of this study is to isolate lotus seed protein and generate calcium-binding peptides by enzymatic hydrolysis. Structural characterization of lotus seed calcium-peptide (LSPIH-Ca) complex was performed. Further, this study investigated osteogenic effect of LSPIH-Ca in mesenchymal stem cells and bioavailability by the Caco-2 calcium transport assay. Finally, the sequences of calcium-binding peptides were identified.

Materials

Lotus seeds were procured from a nearby market. Cell culture media and certain components were obtained from Gibco-BRL (Gaithersburg, MD, USA). Primary antibodies for extracellular signal-regulated kinase (ERK), p-38, c-Jun N-terminal kinase (JNK), Osteocalcin, collagen type I alpha 1 chain (COL1A1), distal-less homeobox 5 (Dlx5), phosphorylated-ERK (p-ERK), phosphorylated-p38 (p-p38), osterix, runt-related transcription factor 2 (Runx2), phosphorylated-JNK (p-JNK), b-actin, and p-p38 were

Protein isolates of lotus seed

Alkaline extraction is a well-established and effective technique commonly employed for obtaining high-quality protein isolates. In this study, lotus seed protein isolate

(LSPI) was obtained with a purity of 83.80 %. Additionally, SDS-PAGE analysis revealed distinct protein bands, reflecting the presence of proteins with varying molecular weights (Fig. S1). A light band at 140 kDa suggested a low amount of high-molecular-weight protein. Moderate amounts were found in the 35–50 kDa range, but

Conclusion

Alcalase hydrolysis effectively produced calcium-binding peptides from lotus seed and facilitated LSPIH-Ca complex formation. Spectroscopic study revealed that calcium reacted with LSPIH to generate LSPIH-Ca complex via amide, carboxyl, carbonyl groups, and carboxylate oxygen atoms. Furthermore, the structural alterations from LSPIH to LSPIH-Ca complex, as evidenced by SEM and EDS, were attributed to interactions between peptides and calcium ions. Subsequent findings shown that LSPIH-Ca complex

Source: International Journal of Biological Macromolecules

Boba-Like Edible Beads Trap Fats and May Promote Weight Loss

Microbeads made from green tea and seaweed-derived compounds may offer a safer, less invasive way to lose weight than current options.

A fat-absorbing microbead, white and pearl-like, lies on a black speckled surface.

Boba pearl-inspired, fat-absorbing microbeads may promote weight loss by increasing fat excretion.



Despite Ozempic's ultra-popularity, some patients can't take this drug due to pre-existing health conditions such as thyroid and pancreatic disorders. Thousands of lawsuits have also been filed against the drug over safety concerns—a major one noting vision losses is currently awaiting the court's decision.

Bioengineer Junling Guo at Sichuan University wanted to provide a safer option to help patients lose weight. His team recently developed edible fat-absorbing microbeads, shaped like boba pearls and made from chemical compounds derived from green tea and brown seaweed.¹ The beads work locally in the gut rather systemically in bloodstream, which may reduce the risk of side effects. The team's results were published in *Cell Biomaterials*.

"Polyphenols [the green-tea derived compound] are the ideal building block because they can form multiple interactions," said Yue Wu, Guo's graduate student, when she presented the team's findings at the Fall 2025 American Chemical Society meeting. "The microbeads also interact with both fat and water, making them both stable and biocompatible."

The researchers observed that the fat-trapping microbeads absorbed various dietary fats, from peanut butter to pork fat, with up to 81 percent efficiency in vitro. "This suggests that they can be effective in real-world cases, where fat sources are highly diverse," Wu said. The team also found that the microbeads could reduce weight gain in rats that consumed a high-fat diet by about 17 percent relative to their counterparts who ate the same diet but without the beads. The microbead-treated rats also had significantly lower levels of fat in their bloodstream.

While semaglutide-based drugs like Ozempic work mainly by reducing appetite, other drugs, such as orlistat, limit fat absorption in the gut. This is also how Wu and Guo's microbeads work. Orlistat is currently the only medication targeting fat absorption that's been approved by the US Food and Drug Administration. But because it hinders fat absorption by increasing their excretion through feces, diarrhea is a common side effect.

So, Wu and Guo's team tested if their boba pearl-

inspired drug could help alleviate this problem. The researchers compared the feces of rats that ate a high-fat diet supplemented with the microbeads to feces excreted by their counterparts on the same diet but treated with orlistat. They observed that rats given the microbeads had no diarrhea and excreted microbeads swollen with absorbed fats within hours. The orlistat-treated rats, on the other hand, had watery feces. These results indicate that these microbeads could help increase fat excretion without the commonly associated gastrointestinal side effect.

The researchers are currently recruiting patients, some of whom can't take or don't respond to semaglutide-based drugs, for an early-phase clinical trial in China to test these microbeads.

Source: The Scientist

Omega 3 fatty acids help brain function, heart health: Otorhinolaryngologist explains how it is different from Omega 7

While both support overall health, Omega-3 focuses more on heart and brain health, whereas Omega-7 has benefits more geared towards skin, hair, and eye health.

Omega-3 fatty acids, which can be found in fish and flaxseed, yield a number of health benefits, including the prevention of heart disease, a 2016 study published in the National Centre for Biotechnology Information found. In an interview with HT Lifestyle, ENT/otorhinolaryngologist Dr Vishal Tyagi, consultant, Fytika Healthcare Group, said dietary fat like omega-3 has experienced a complete flip in the recent past – from being dreaded to something that must be harnessed. Also read | Are you having enough omega-3? Know 5 common food sources and when you should take supplements

Omega-3 and Omega-7 fatty acids contribute to overall health, but their specific benefits differ.

What Indians must know about fatty acids

The doctor explained that omega-3 and omega-7 fatty acids are both essential for our health, but they have different benefits and sources. He said, "Omega-3 fatty



acids are one of the better fats and are acclaimed universally for their overall goodness. Recently, omega-7 fatty acids also garnered attention for their potential benefits in skin and metabolic health. As the Indian consumer moves toward preventive health care, awareness around the functions of fat and its dietary sources allows appropriate nutritional selection."

What are omega-3 fatty acids?

Dr Tyagi explained: "The human body cannot produce the omega-3 fatty acids but must consume them as part of the nutrition. Omega-3 fatty acids assist in regulating cell membrane composition, brain function, heart health, and inflammation regulation. Of the three omega-3 fatty acids, ALA (in flaxseeds, chia seeds, and walnuts), EPA, and DHA (in oily fish, including salmon, tuna, and sardines) are the others. Omega-3s are also overwhelmingly crucial, particularly for a pregnant woman, heart health, and joint inflammation."

What are omega-7 fatty acids?

According to Dr Tyagi, "Omega-7s, also known as palmitoleic acid, are monounsaturated fatty acids that our body makes, but taking them in some way or another through diet helps. Omega-7 has been found in macadamia nuts and sea buckthorn oil to improve insulin sensitivity, enhance fat metabolism, prevent inflammation, and assist skin. Metabolic syndrome, in which diabetes is included, is spreading fast in India, and omega-7 brings great relief."

Omega-7 has been found in macadamia nuts and sea buckthorn oil to improve insulin sensitivity.

What are the benefits of omega-3 fatty acids?

Omega-3 lowers triglycerides, blood pressure, and

coronary heart disease, Dr Tyagi said, and added, “Omega-3 reduces pain and inflammation in rheumatoid arthritis. DHA assists in the brain and eyesight development of a baby during pregnancy. Omega-3 eases skin diseases like eczema, is beneficial in bone health, and conditions hair and scalp.”

What are the advantages of omega-7 fatty acids?

Dr Tyagi said, “Less researched, but with their own special, pretty advantages, are the omega-7s. They reduce insulin resistance and are therefore a pleasant friend to type 2 diabetes and metabolic syndrome. Omega-7s lower cholesterol levels and enhance fat metabolism. Applied to the skin, they are an all-natural emollient, bringing moisture and flexibility, and a good solution for anyone with dry or irritated skin.”

How much should you take?

For omega-3s, Dr Tyagi suggested:

- Adults need 1.1 to 1.6 grams per day of ALA, a tablespoon of ground flaxseeds, or 1.5 tablespoons of chia seeds.
- For EPA and DHA, the optimal dose is 250–500 mg/day, or two weekly servings of 100–150 grams of fatty fish.
- Some cardiovascular disease patients take no more than 1,000 mg/day in fish oil capsules.

For omega-7s, he added:

- With or without regulation, there is a basis for 100 to 420 mg/day palmitoleic acid.

- It is best tolerated with 1 tsp (5 ml) sea buckthorn oil or 1 serving (20–25 grams) macadamia nuts.
- Sea buckthorn capsules are readily available and accessible in India.

Omega-3 vs omega-7



According to Dr Tyagi, “Omega-3s support the function of the brain, heart, and joints, while omega-7s and their associated metabolic efficiency are connected to our skin and reduce inflammation. Omega-rich foods like fatty fish, flaxseeds, sea buckthorn oil, or macadamia nuts, and sometimes structured supplements of a better quality are increasingly being organised to even have the scope to facilitate the health outcomes of Indian consumers to promote their long-term health. The best piece of advice is to talk to a medical professional about your own medical needs and supplements.”

Source: The Hindustan Times

FENNEL SEED ESSENTIAL OIL

Introduction :

Since ancient times, fennel has been used as an aromatic and therapeutic herb to flavor liqueurs, breads, salads, fish, and cheeses. The seeds of this extremely fragrant herb are used to flavor baked goods, beverages, and herb combinations. One can eat the seeds, leaves, and stems. Fennel seed has high levels of carbohydrates, moisture, protein, fat, dietary fiber, calcium, phosphorus, iron, salt, potassium, and vitamins. Fennel seeds have 1-4 percent essential oil and 20 percent fatty oil. The primary components of essential oil are fenchone and trans-anethole.

The Apiaceae family includes the ancient spice plant fennel (*Foeniculum vulgare* Mill), which is regarded as one of the most significant medicinal herbs in the world. The well-known perennial plant *F. vulgare* is indigenous to the Mediterranean region. It is utilized to prepare herbal drugs and is being utilized for a range of respiratory, gastrointestinal, and hepatoprotective conditions.

Essential oils (EOs) are the main constituents of fennel seeds and are being used as flavoring agents in various foods, cosmetic, and pharmaceutical products. Estragole (methyl chavicol) was the primary chemical component of fennel seed EOs. It is farmed for profit in Russia, India, China, and Japan.

Botanical Name

Foeniculum vulgare L. **It is a flowering plant species in the carrot family, Apiaceae.**



Harvesting and Extraction

Harvesting and extraction of fennel seed essential oil involves gathering mature seeds just as they turn brownish-green, drying them, crushing the hard outer shells, and processing them via steam distillation or solvent extraction to yield a pale yellow, aromatic oil.

Harvesting Process

Timing: Gather seed heads when they flatten and turn from green to a brownish color, but before they fully shatter or drop.

Cutting: Snip entire seed head stems carefully in the morning or over a collection container to prevent seed loss.

Drying: Place the cut stems or gathered seeds inside a paper bag in a warm, dry, well-ventilated area for 14 days until fully dry.

Cleaning: Separate the dried seeds from any remaining plant debris or dirt before processing.

Extraction Methods

Crushing: Gently crush or grind the dried fennel seeds right before processing to break the tough seed coat and maximize volatile oil release.

Steam Distillation (Commercial Standard): Pass hot steam through the crushed seeds in a stainless steel chamber; the vaporized oil and steam travel through a cooling condenser where they liquefy and separate from the aromatic water (hydrosol). Typical yields range from 2% to 4%.

Solvent or Alternative Extraction: Utilize organic solvents (like acetone or hexane via Soxhlet apparatus) or advanced methods like supercritical CO₂ for higher recovery rates (up to 6%), though steam distillation remains preferred for pure therapeutic grades.

Advanced Extraction Techniques: New extraction techniques, such as supercritical fluid extraction (SFE), microwave-assisted extraction (MAE), and ultrasound-assisted extraction (UAE).

Essential Oil Content and Composition : The essential oils of dried fruits were extracted by hydrodistillation method using Clevenger apparatus, and analyzed by GC and GC-MS. The essential oil content of fruits were 1.31, 1.18, and 1.26 %, at pasty, waxy and full ripening stages, respectively. The main oil components at different fruit maturity stages were found to be trans-anethol (84.1 -86.1 %), fenchone (7.13 - 8.86 %), limonene (3.0 - 3.3 %), and methyl chavicol (2.5 - 2.7 %).

Benefits And Uses

Fennel essential oil has been used for centuries for a number of health concerns due to its licorice flavor and aroma. This is also good for use for culinary purposes and beneficial for promoting better digestive health and respiratory health. Fennel natural essential oil is one of the best natural essentials for skin digestion. Its distinctive and sweet scent makes it the perfect natural product in aromatherapy. Fennel essential oil weight loss is also effective to produce better results if you have gained weight unexpectedly.

Fennel Essential Oil for Skin: Fennel seed essential oil contains anti-inflammatory properties that make it a robust product to soothe and calm your skin. It's helpful to make your skin healthier. Fennel Essential Oil for skin care possesses active compounds like anethol, limonene, and chavicol that make it good to lift the skin, as well as minimize pores and even out imperfections. Meanwhile, this natural essential oil has anti-aging properties and works effectively to deal with the epidermis to strengthen, protect and re-energize skin. This is also great for face against environmental stressors like – UV RAYS, toxins, and pollutants. Fennel essential oil is one of the finest natural products good for premature skin aging and protects the skin from free radicals. Fennel essential oil hormones can balance the hormones to a certain degree where they would deliver the intended results.

Use: Calming and soothing topical effects of Fennel Essential Oil make it best for applying directly to the Skin. In case you've sensitive skin then you can dilute the Fennel Oil with the best carrier oil like fractionated coconut oil to avoid any type of skin irritation

Fennel Essential Oil for Hair

Fennel Essential Oil contains the antioxidant and antimicrobial properties that make it the perfect natural product for hair growth, dandruff, scalp itchiness, hair breakage, and hair fall. Fennel Essential Oil offers you lots of hair benefits and is listed as one of the best natural essential oils for hair where it's great to deal with cellulite. Fennel's nutritional value makes it effective for skin as well as for hair problems. Fennel seeds contain the necessary nutrients including – calcium, phosphorus, magnesium, iron and vitamin C where all these work effectively to prevent hair loss.

Fennel Seed Essential Oil for Relaxation:

There are so many natural essential oils for relaxation, anxiety and depression issues. But Fennel Essential Oil has its own significance. This natural essential oil offers you maximum benefits in the context of low mood, day-to-day stress, etc. Its aroma makes this possible.

Use: To get the relaxation, you need to combine one drop of fennel volatile oil with an appropriate amount of essential oil or carrier oil. You may choose the Lavender essential oil where 2 drops of this natural essential oil are sufficient. After this you can run this natural essential oil on your neck, chest and on your hands. Now take deep breaths slowly. In addition to the above way, you can use this Fennel essential oil in a Diffuser.

Promote Healthy Metabolism

Fennel essential oil is quite effective for promoting healthy metabolism, liver function and circulation. This natural essential oil is an excellent natural product for the lung's health as well as the respiratory tract.

Use: To promote healthy metabolism, it's good to know how to intake the fennel seed essential oil. For this, you need to add 1-2 drops of Fennel essential oil in the water or another beverage.

*Compiled by:
Dr. S. Adhikari*

LAUGH AND LOUD

Q. What do you call an acid with an attitude?

A. A-mean-o Acid

Q. What type of fish is made out of 2 sodium atoms?

A. 2 Na.

Q. Why are Helium, Curium, and Barium the medical elements?

A. Because if you can't heal-ium or cure-ium, you bury-um. A science teacher tells his class, Oxygen is a must for breathing and life. It was discovered in 1773. A blonde student responds, Thank God I was born after 1773! Otherwise I would have died without it.

Q. How do astronomers organize a party?

A: They are a planet.

Sherlock Holmes and Dr Watson went on a camping trip. After a good meal and a bottle of wine, they laid down for the night, and went to sleep. Some hours later, Holmes awoke and nudged his faithful friend Watson, look up at the sky and tell me what you see. Watson replied, I see millions and millions of stars. What does that tell you? Watson pondered for a minute. Astronomically, it tells me that there are millions of galaxies, and potentially billions of planets. Astrologically, I observe that Saturn is in Leo. Horologically, I deduce that the time is approximately a quarter past three. Theologically, I can see that God is



all powerful and that we are small and insignificant. Meteorologically, I suspect that we will have a beautiful day tomorrow. What does it tell you? Holmes was silent for a minute, then spoke. It tells me that someone has stolen our tent.

Q. What do you call a guy who's really loud?

A. Mike.

Q. Is Google male or female?

A. Female, because it doesn't let you finish a sentence before making a suggestion.

MEMBERS' PAGE

DON'T GET HYPER

by R.C. ARORA (Ex. Manager Q.C. - S.F.F.I., New Delhi)

These days, hypertension is a very common problem. It is a lifestyle disorder - not something due to a faulty lifestyle. Hypertension can vary depending upon different personality types. People with a **pitta** personality, for instance, who suffer from hypertension, are usually prone to headaches, red eyes and digestive problems.

In the **kapha** kind of hypertension, we see that people, besides having high blood pressure, will also be obese and prone to high cholesterol.

In the **vata** kind of hypertension, we find that blood pressure keeps fluctuating and is connected to stressful situations. These people also have problems sleeping and suffer from gas.

You can use an integrated method to manage hypertension.

Nutrition

The main emphasis is on avoiding foods that promote high blood pressure and replacing them with foods that lead to a normalising of blood pressure. Avoid non-vegetarian options, eggs, alcohol and tobacco.

Foods that help during an attack of high blood pressure are vegetable juices - both raw and fresh juices containing parsley, celery, spinach, carrot and raw potato. These ingredients act at many levels in the circulatory system to decrease blood pressure. Firstly, they help to balance the calcium, sodium and potassium levels of the body.

These salts have a key influence in normalising the flexibility of the blood vessels, which ultimately helps in the lowering of blood pressure.

Many research papers have also proved that consuming a clove or garlic daily has a beneficial effect in lowering blood pressure. Amla, in any form, is also beneficial. Other foods that are helpful include watermelon seeds and khus khus seeds - these should be crushed, mixed with a little milk and taken at night with an apple.

During an attack of high blood pressure, one must restrict the quantity of food and at night, just have an apple with a glass of skimmed milk to which the crushed seeds have been added.

Pranayam and Yoga

Yoga is excellent when it comes to controlling high blood pressure. You can do the following pranayams - anilom vilom, sheetali, ujjayi and brahmbari - to manage episodes of high blood pressure. Omkara meditation - chanting "Om" - is a powerful way to control your nerves.

Lifestyle Therapies

Chamomile tea and chamomile oil are very relaxing for sufferers. Lavender oil can also be applied on the pulse points at night before you go to sleep, and inhaled.



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