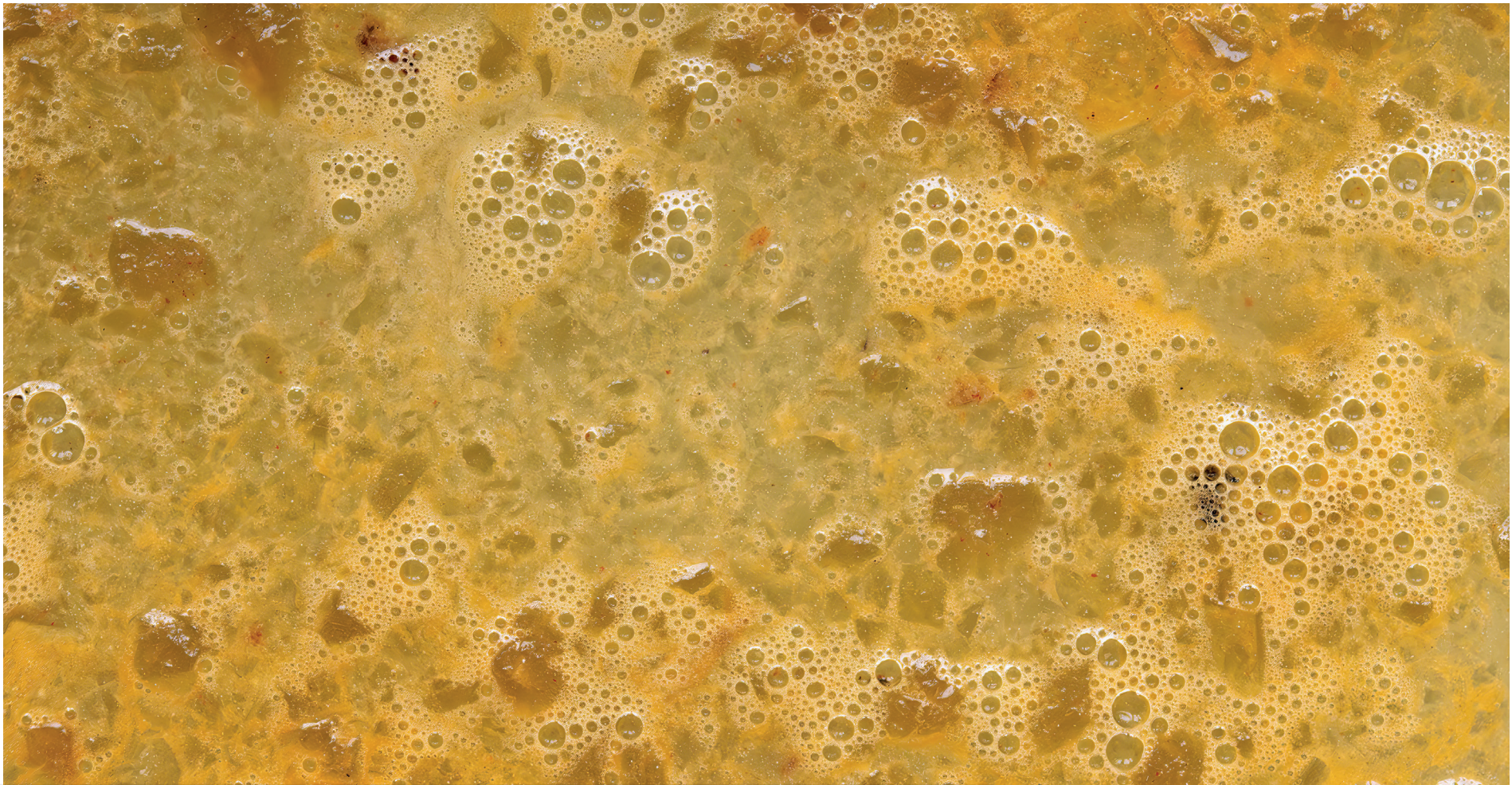




THE SKINNY BEHIND TRENDS IN GREASE THICKENER TECHNOLOGY

Since the 1970s, lithium greases have dominated the global market. However, fluctuations in the lithium market combined with regulatory restrictions on lithium salts have raised concerns about the long-term sustainability of lithium greases. Dr Raj Shah, Rachel Ly and Michael Lotwin examine the market challenges affecting lithium greases, the latest developments in calcium grease formulation and the future role of bio-based oils and engineered nano additives in shaping a more sustainable lubricants industry

Recent price fluctuations and disruptions in the lithium market

In recent years, lithium grease accounts for approximately 70% of global grease production. This is due to their favourable thermal stability, water resistance and compatibility with diverse additive systems. It makes them especially prevalent in automotive and wheel bearing applications [1].

Over the past decade, however, the lithium market has experienced pronounced price fluctuations.

Between 2017 and 2019, lithium prices rose to roughly three times their 2015 levels. This was due to accelerating demand from lithium-ion battery production for electric vehicles (EVs).

A second and more severe price surge occurred in 2022. Lithium prices exceeded five times the value of 2015 with supply deficits and global disruptions associated with the Covid-19 pandemic.

Although prices for lithium carbonate and lithium hydroxide declined by more than 80% during 2023-2024, global reliance on lithium soap thickeners continues to fall.

In 2023, lithium-based thickeners accounted for 58% of grease production. This was down from 70% in 2020, highlighting declining confidence in long-term supply stability [2,3].

Price fluctuations and supply uncertainty have affected manufacturers’ ability to secure lithium hydroxide for grease production. This prompted some to reduce and even discontinue lithium grease development.

Other concerns include the expansive growth in EV adoption and its effect on lithium availability. However, this perspective overestimates the risk of lithium hydroxide scarcity.

Battery-grade lithium hydroxide meets significantly higher standards compared to those used in grease formulations.

Furthermore, lithium grease production represents less than 10% of total lithium hydroxide demand. This indicates that EV expansion does not pose a direct supply constraint on grease manufacturing [4].

Meanwhile, lithium grease manufacturers are facing increasing regulatory and safety challenges.

In 2021, the European Chemicals Agency classified lithium carbonate, lithium hydroxide and lithium chloride as Category 1A reproductive toxins, emphasizing the implementation of safety measures for workers and end-users.

These lithium salts, commonly used in batteries, greases and pigments, were identified as posing potential risks to fertility and unborn or breastfed children. This classification raised investment concerns across lithium-related industries, including mining, processing and recycling, with possible extensions to lithium grease production [5].

While many industry leaders have argued these restrictions conflict with long-term decarbonisation goals, the European Union has cited research evidence linking lithium exposure during pregnancy to adverse developmental effects.

As a result, lithium price instability and heightened regulations continue to introduce uncertainty surrounding the sustainability, affordability and long-term viability of lithium-based greases [6].

Market innovations for calcium greases

Over the past decade, calcium greases have emerged as viable alternatives to lithium-based greases. This is due to competitive tribological performance and more cost-stable production pathways [7].

In 2023, hydrated and anhydrous calcium thickeners, calcium

sulphonates, and calcium complex thickeners accounted for 24% of global grease production. This compared to 15% in 2020, signaling a measurable shift away from lithium-thickened greases.

As of 2025, approximately 46% of global grease formulations used in marine and heavy-duty machinery incorporate overbased calcium sulphonate thickeners. While 34% of lubricating systems in the paper industry have adopted these formulations within the past five years [8].

In recent years, lithium grease accounts for approximately 70% of global grease production.

Calcium greases generally exhibit high dropping points, strong shear stability and good oxidative resistance. This makes them suitable substitutes for lithium greases in demanding service conditions.

A key formulation difference between lithium and calcium greases lies in thickener concentration. Lithium greases typically contain 7-8% thickener. Whereas calcium greases may require 30-35% to achieve comparable consistency.

While higher thickener content can result in stiffer greases and reduced pumpability, it also contributes to the inherent corrosion resistance and load-carrying capability characteristic of calcium sulphonate systems.

These attributes have enabled widespread adoption in marine and H1 food-grade applications. Here, corrosion protection and water resistance are critical.

Despite their rapid growth, calcium sulphonate greases currently represent less than 7% of the global grease market. This indicates substantial progress needed to reach greater market adoption [7].

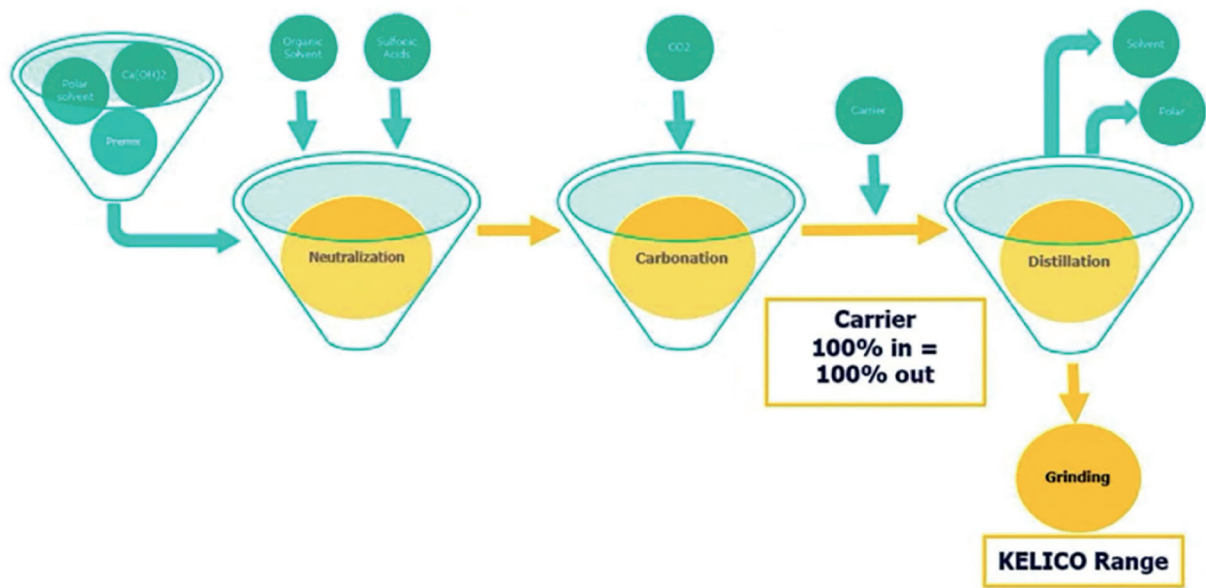


Figure 1: SEQENS's one-step overbased calcium sulphonate grease formulation process [13]

Recognising this shift, major lubricant manufacturers have developed their own calcium grease technologies.

In 2023, Chevron introduced the Rykon product line. This is a premium calcium sulphonate grease designed to deliver high load-carrying capacity, durability under extreme pressure, reduced relubrication frequency and extended service life [9,10].

That same year, LANXESS optimised three H1-compliant food-grade calcium sulphonate complex greases with enhanced resistance to acidic environments, high oxidation stability, and improved mechanical durability [11].

In 2024, more than 22 new overbased calcium sulphonate grease formulations, including synthetic, nano-enhanced and food-grade variants, entered the TBN300 and TBN400 markets [8].

Among these, FUCHS Lubricants released RENOLIT CSX ULTRA. This is formulated for heavy mobile and mining equipment, offering strong rust protection in chemically-treated water and high shear resistance for bearings, gears and pin-and-bushing interfaces [12].

Collectively, these developments recognise calcium greases as versatile, high-performance alternatives to conventional lithium greases across automotive, food-processing and mining sectors.

Eco-friendly calcium greases

Currently, there is a growing demand to align grease innovations with environmental sustainability goals.

As a result, lubricant manufacturers and researchers are not only engineering greases with improved tribological performances, but are also examining based oils, thickeners and additives for potential biodegradability, renewability and eco-toxicity reduction.

The following sections introduce the newest development in bio-based calcium-thickened greases. This has shown promise in offering high tribological performance without compromising environmental responsibility.

The first marketed overbased calcium sulphonate biolubricant

In 1960, McMillan patented a two-step process for producing calcium sulphonate greases. In this process, amorphous overbased calcium sulphonate was prepared in a mineral or synthetic oil and then transformed with acid, promoters and lime. The promoters and water in the amorphous calcium carbonate would then be eradicated to yield crystalline calcite.

By the 1980s, SEQENS, a global leader in pharmaceutical solutions and specialty ingredients, developed a one-step overbased calcium sulphonate grease carbonation production process. This aimed to shift away from necessitating a mineral-oil precursor in grease formulations.

As shown in Figure 1, the innovative process involves mixing all ingredients, including sulphonic acid, base oil and lime, and reacting them with carbon dioxide to form a complex mixture of calcium sulphonate, calcium carbonate and 100% of a chosen carrier or base oil [13].

Throughout the 20-year industrialisation of this grease process, SEQENS has gradually transitioned from paraffinic base oils to naphthenic oils to rapeseed oil as a direct response to the increasing demand for biodegradability in the marine sector.

In 2021, SEQENS first introduced KELICO V, a new line of 100% ester-based overbased calcium sulphonate greases formulated from rapeseed oil (Figure 2) [14].

KELICO V is classified as an environmentally acceptable lubricant

(EAL). It is distinguished as the only biodegradable, minimally toxic and non-bioaccumulative overbased calcium sulphonate grease available on the market.

It combines high pressure and temperature resistance with superior water repellency and anticorrosion performance for optimal marine adaptation. It exceeds that of conventional overbased calcium sulphonate greases [13].

By establishing a precedent with its green grease formulation method and successful development of a bio-derived overbased calcium sulphonate, SEQENS paves the way for lubricant manufacturers to create customised formulations with renewable base oil feedstocks in a single-step process. This offers lubricant optimisation with environmental sustainability.



Figure 2: SEQENS's KELICO V 2046 [14].

Research studies on bio-sourced calcium greases

The transition toward more sustainable lubricants has brought more attention towards bio-based greases.

Unlike conventional greases, bio-based calcium greases are formulated with vegetable oils, agricultural waste esters or chemically modified renewable feedstocks.

Recent research has highlighted the advantageous properties of certain lipid molecules.

Most plant-based oils comprised of fatty acid (FA) esters form a thin film at the contact points between surfaces. This reduces wear and oxidation while extending the lifespan of lubricated surfaces [15, 16].

Triacylglycerol (TAG) [17, 18, 19], wax esters [20], estolides [15, 21] and erucic acids [22], in particular, contain long-chain fatty acids that improve oxidation stability and lubrication efficiency.

The following research studies demonstrate the application of renewable ester base oils in calcium grease development with tribological properties comparable to, and even surpassing, that of conventional greases.

Sample	Base Oil (Palm Oil) (%)	Thickener	Additives
PB1	80	Calcium Complex Soap (12%)	Calcium Carbonate(5%), (3%) Hydroxyapatite
PB2	70	GMS (30%)	-
PB3	70	SW (30%)	-
PB4	80	GMS (4%), SW (15%)	Hydroxyapatite (!%)
PB5	85.5	Calcium Complex Soap (10%)	Calcium Carbonate(4%), (0.5%) Hydroxyapatite
PB6	80	GMS (15%), SW (5%)	

Figure 4: Composition of palm oil-based greases [24]

In 2022, Babu Kizhakkeappillil aimed to create a biodegradable calcium-thickened grease using coconut oil while still attaining performance comparable to existing commercial greases [23].

Coconut oil has favourable tribological properties compared to other vegetable oils. But it suffers from a high pour point (27°C), constraining its industrial lubricant application.

Thus, chemical modification converted coconut oil to coconut oil methyl ester (CME) that lowered the pour point value to -5°C [23].

The resulting CME was mixed with calcium stearate thickener to form a NLGI grade 3 calcium grease, known as the calcium-based coconut oil methyl ester grease (CACME grease); its tribological properties were then evaluated against a commercial sample of the same grade, referred to as COM grease.

Properties	CACME grease	COM grease
Cone penetration	233 (unworked) 245 (500 strokes)	243(unworked) 248 (500 strokes)
Rolling Stability	235	248
Water wash out	39°C–0.11 g 79°C–0.24 g	39°C–0.13 g 79°C–0.23 g
Wear diameter, mm	0.493	0.614
Coefficient of friction	0.069	0.092
Corrosion test	Ia	Ib
Operating temperature	–7°C and 108°C	–15°C to 106°C

Figure 3: Physical properties of CACME grease and COM grease [23]

As shown in Figure 3, CACME grease exhibited an extensive operational temperature range, between 7°C and 108°C, with grease stability, consistency and coefficient of friction to be consistent with that of COM grease.

Moreover, a 0.5 HP centrifuge pump was used to evaluate the grease performance of both samples; the CACME grease displayed 6.9%, 1.8%, and 4.7% improved efficiency, discharge flow and power consumption, respectively, compared to its commercial counterpart [23].

These improvements suggest the CME-based grease not only matches, but also enhances operational performance in pumping equipment. With promising industrial adoption into becoming a greener, high-performance grease alternative.

In 2024, Sapnar et al. investigated palm oil-based lubricating greases formulated with varying concentrations of thickeners and additives, including stearic acid, calcium hydroxide, glycerol monostearate (GMS), soy wax (SW) and hydroxyapatite (HA), to enhance tribological performance, mechanical stability and thermal resistance while maintaining biodegradability and low toxicity [24].

Figure 4 lists several formulations prepared using 70-85.5% palm oil combined with GMS, SW and calcium complex soap thickeners.

Under ASTM four-ball wear testing, all bio-greases demonstrated competitive weld strength and coefficient of friction as well as significantly smaller wear scar diameter compared to petroleum-based greases (Figure 5). This corresponds to a 15-25% reduction in friction and a 20-30% increase in wear resistance.

Notably, the formulation containing 85.5% palm oil and 10% calcium complex soap, reinforced with hydroxyapatite and carbonate additives, achieved the highest performance by attaining NLGI grade 4 stiffness with superior wear resistance and load-carrying capacity.

Overall, calcium-based greases outperformed both GMS- and SW-based greases by offering greater thermal stability.

Other than thickener selection, the integration and compatibility of additives, specifically HA and CaCO3 in this case, had an integral role in reducing wear and enhancing grease stability

Parameter	PB1	PB2	PB3	PB4	PB5	PB6	Commercial Grease GC-I
Friction Coefficient	0.084	0.079	0.083	0.081	0.080	0.082	0.079
Four-Ball Wear Scar (mm)	0.68	0.61	0.66	0.60	0.58	0.63	1.01
Last Non-Seizure Load (kg)	315	355	340	375	390	360	400
Weld Load (kg)	400	450	440	460	480	450	500
Thermal Stability (°C)	180	160	155	170	185	165	200
Appearance	White creamy	Smooth creamy	Smooth opaque	White dense	White oily	Light creamy	Grey/silvery

Figure 5: Tribological performance of palm oil-derived greases and commercial grease [24]

while exhibiting chemical synergy with palm oil and various thickening agents [24].

Ultimately, these findings suggest the potential of calcium as a thickener for next-generation bio-greases. This highlights the optimal performance lies in strategic integration of base oils, thickeners and tailored additives.

Figure 5: Tribological performance of palm oil-derived greases and commercial grease [24]

Future perspectives: formulation science with bio-greases and nano additives

The calcium grease industry continues to expand through market-driven innovation and the integration of bio-derived base oils with calcium grease formulations.

Recent industrial and academic studies have demonstrated that bio-greases formulated with calcium soaps or overbased calcium sulphonate thickeners can achieve tribological performance comparable to, and in some cases exceeding, that of conventional commercial greases.

Looking ahead, research efforts have increasingly shifted toward enhancing additive packages through the incorporation of engineered nano additives.

Ester- and vegetable-oil-based base stocks improve biodegradability, sustainability and environmental compliance. But additives remain the primary indicators of wear resistance, corrosion protection and thermal conductivity.

Nano additives have attracted interest due to their distinct tribological mechanisms. These include rolling effects that reduce friction, surface repair and polishing and the formation of protective interfacial layers that act synergistically with lubricant-derived tribofilms [25].

Commonly investigated materials include metal oxides, metal-based and carbon-based nanoparticles, boron nitride and molybdenum disulphide (MoS₂). All of these have shown performance benefits in bio-lubricants [25].

Despite these advances, limited attention has been given to the complex chemical interactions between nano additives and lubricant materials.

Challenges such as particle agglomeration under thermal and mechanical stress, as well as secondary reactions between nanoparticles and based oil constituents, remain insufficiently understood.

Addressing these issues is essential for developing stable, scalable formulations.

Simultaneously, comprehensive toxicity assessments and life cycle analysis must be prioritised. The sustainability of bio-greases depends on their full value chain, from feedstock production and processing to lubricant use and final disposal.

Economic considerations also remain a major obstacle. Bio-lubricant production costs are typically 10-20 times higher

than those of conventional lubricants. This limits large-scale commercialisation [26].

Future research should therefore focus on additive-thickener-base oil compatibility, life cycle optimisation and cost-reduction strategies.

Only with coordinated progress in these areas can calcium-based bio-greases emerge as durable, high-performance and environmentally responsible lubrication solutions of the future.

Conclusion

In summary, the grease industry is undergoing a transition.

Lithium greases, once the dominant choice, are losing reliability due to price fluctuations and growing health concerns. While calcium greases are rapidly emerging as a competitive alternative.

Recent market analysis indicates that industrial leaders are exploring novel calcium greases formulations with enhanced biodegradability to meet ecological demands.

When combined with bio-based oils and advanced additives, calcium greases are outperforming commercial greases, both tribologically and environmentally.

Nevertheless, challenges remain. These include high production costs, uncertainties regarding nanoparticle additive toxicity and the complex compatibility with oils, thickeners and additives.

With these developments, calcium greases are prepared to define the next generation of lubricants, delivering high performance without compromising environmental responsibility.

References

[1] Aikin, Andrea R., "The future of lithium greases," Society of Tribologists and Lubrication Engineers, Nov. 2022. https://www.stle.org/files/TLTArchives/2022/11_November/Feature.aspx.

[2] Jennifer L., "Understanding Lithium Prices: Past, Present, and Future," Carbon Credits, May 2024. <https://carboncredits.com/understanding-lithium-prices-past-present-and-future/>.

[3] Sullivan, Tim, "NLGI: Lithium Thickeners Still Declining," Lubes'n'Greases, Jun. 2024, https://www.lubesngreases.com/lubereport-americas/9_26/nlgi-lithium-thickeners-still-declining/.

[4] Sosa, Yulia, "An update on lithium base greases," Society of Tribologists and Lubrication Engineers, Dec. 2024. https://www.stle.org/files/TLTArchives/2024/12_December/Cover_Story.aspx [stle.org](https://www.stle.org).

[5] Holman, Jacqueline, "Europe proposal to classify lithium as toxic could hinder battery supply chain," S&P Global, Jun. 2022. [https://www.spglobal.com/commodity-insights/en/news-research/latest-news/metals/062822-europe-proposal-to-classify-](https://www.spglobal.com/commodity-insights/en/news-research/latest-news/metals/062822-europe-proposal-to-classify-lithium-as-toxic-could-hinder-battery-supply-chain)

[lithium-as-toxic-could-hinder-battery-supply-chain](#).

[6] Zimmermann, Antonia and Cater, Leonie, "Toxic or magic? Batteries industry freaks out over EU proposal to classify lithium as a toxin," Politico, Jul. 2022, <https://www.politico.eu/article/eu-commission-toxic-or-magic-batteries-industry-freaks-out-over-proposal-to-classify-lithium-as-a-toxin/#:~:text=The%20European%20Chemicals%20Agency%27s%20Risk,substances%20for%20the%20green%20transition>.

[7] "Spotlight on Grease," Lubes'n'Greases Magazine, Jun. 2021, https://www.lubesngreases.com/magazine/27_6/spotlight-on-grease-4/.

[8] "Overbased Calcium Sulfonate Grease Market Size, Share, Growth, and Industry Analysis, By Type (TBN300, TBN400), By Application (Marine Equipment, Heavy Mobile Equipment, Paper Machine, Rolling Mill Bearing), Regional Insights and Forecast to 2033," Market Growth Reports, Aug. 2025. <https://www.marketgrowthreports.com/market-reports/overbased-calcium-sulfonate-grease-market-115140>.

[9] Sutton, Zach, "Introducing a New Line of Greases to Keep Equipment Humming," Chevron Lubricants (From Chevron), Oct. 25, 2023. [Online]. Available: https://www.chevronlubricants.com/en_us/home/learning/from-chevron/industrial-machinery/introducing-a-new-line-of-greases-to-keep-equipment-humming.html.

[10] "Chevron Introduces New Rykon Formula to Grease Product Line," Business Wire, Feb. 2024, <https://www.businesswire.com/news/home/20240205529065/en/Chevron-Introduces-New-Rykon-Formula-to-Grease-Product-Line>.

[11] Moon, Mary, "LANXESS New Generation of H1 Food Grade Calcium Sulfonate Greases," Society of Tribologists and Lubrication Engineers, Nov. 2023. https://www.stle.org/files/TLTArchives/2023/11_November/LANXESS.aspx.

[12] "FUCHS LUBRICANTS SOUTH AFRICA introduces latest calcium sulphonate grease for mining," FUCHS Lubricants, Apr. 2024. <https://www.fuchs.com/za/en/company/news/news-entry/5965-FUCHS-LUBRICANTS-SOUTH-AFRICA-introduces-latest-calcium-sulphonate-grease-for-mining/> [fuchs.com](https://www.fuchs.com).

[13] Notheaux, Guillaume, "Fully Customizable Calcium Sulfonate Greases for Optimum Performances," Society of Tribologists and Lubrication Engineers, Nov. 2021. https://www.stle.org/files/TLTArchives/2021/11_November/SEQENS.aspx.

[14] "SEQENS Introduces Calcium Sulfonate Biodegradable Greases," Fuels & Lubes, Sep. 2021, <https://www.fuelsandlubes.com/seqens-introduces-calcium-sulfonate-biodegradable-greases/>.

[15] X. Li et al., "Discontinuous fatty acid elongation yields hydroxylated seed oil with improved function," Nature Plants, vol. 4, no. 9, pp. 711–720, Aug. 2018, doi: <https://doi.org/10.1038/s41477-018-0225-7>.

[16] P. Luo, Z. Q. Lan, and Z. Y. Li, "Orychophragmus violaceus, a Potential Edible-oil Crop," Plant Breeding, vol. 113, no. 1, pp. 83–85, Aug. 1994, doi: <https://doi.org/10.1111/j.1439-0523.1994.tb00707.x>.

[17] J. Pichler et al., "A comprehensive review of sustainable approaches for synthetic lubricant components," Green Chemistry Letters and Reviews, vol. 16, no. 1, Jan. 2023, doi: <https://doi.org/10.1080/17518253.2023.2185547>.

[18] D. R. Kodali, "Development, properties and applications of high-performance biolubricants," Elsevier eBooks, pp. 556–595, Jan. 2014, doi: <https://doi.org/10.1533/9780857097385.2.556>.

[19] L. A. Honary, "Biobased Automotive Lubricants," pp. 455–467, Nov. 2012, doi: <https://doi.org/10.1520/mnl6220121210526>.

[20] J. B. Ohlrogge, M. E. Pollard, and P. K. Stumpf, "Studies on biosynthesis of waxes by developing jojoba seed tissue," vol. 13, no. 3, pp. 203–210, Mar. 1978, doi: <https://doi.org/10.1007/bf02533401>.

[21] T. Romsdahl et al., "Nature-Guided Synthesis of Advanced Bio-Lubricants," Scientific Reports, vol. 9, no. 1, Aug. 2019, doi: <https://doi.org/10.1038/>

s41598-019-48165-6.

[22] R. Al Sulaimi et al., "Evaluating the effects of very long chain and hydroxy fatty acid

content on tribological performance and thermal oxidation behavior of plant-based lubricants," *Tribology International*, vol. 185, p. 108576, Jul. 2023, doi: <https://doi.org/10.1016/j.triboint.2023.108576>.

[23] Kizhakkeappillil, Joseph Babu, "Development of calcium-based grease from coconut oil

methyl ester and evaluation of its tribological properties," *Journal of Mechanical Engineering Science*, vol. 237, no. 1, pp. 708–716, 2023. doi: 10.1177/09544062221124006.

[24] Sapnar et al., "Tribological Behaviour of Palm Based Bio Grease with Various Additives

and Thickeners," *International Journal of Intelligent Systems and Applications in Engineering*, vol. 12, no. 23s, 2024, pp. 2837-, <https://ijisae.org/index.php/IJISAE/article/view/7533>.

[25] Aroor et al., "From chemistry to performance: How nano additives are transforming

bio-lubricants for enhanced tribological applications," *Journal of Molecular Liquids*, vol. 425, no. 127242, May 2025. doi: 10.1016/j.molliq.2025.127242.

[26] Malik et al., "A review of recent advances in the synthesis of environmentally friendly,

sustainable, and nontoxic bio-lubricants: Recommendations for the future implementations," *Environmental Technology & Innovation*, vol. 32, no. 103366, Nov. 2023, doi: 10.1016/j.eti.2023.103366.

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