Sourcing the Next Generation of Lubricants:
Exploring the Potential of New Natural Sources of Lubricants for Industrial Applications

Background

► Presently, most lubricants used in machinery, across all sectors, are mineral oils. With ever-depleting petroleum reserves and the rising price of such, there is a need for an alternative: **bio-lubricants**. While there are plenty of contemporary bio-lubricants available (e.g. palm oil, vegetable oils, castor oil), they suffer many of the same drawbacks – namely cost and competition with food usage. Hence, there is incentive for an inedible, inexpensive and green source of lubrication. The reutilisation of waste streams presents itself as one possible solution.

Aim

► The aim of the project is to investigate, develop, and assess a range of bio-based lubricants for industrial applications, with the focus being on the agricultural sector. The desire is to create a circular economy, wherein growers and producers can sell their agrarian waste, which is in turn converted into useable lubricants for their agricultural equipment – see Figure 1 below.

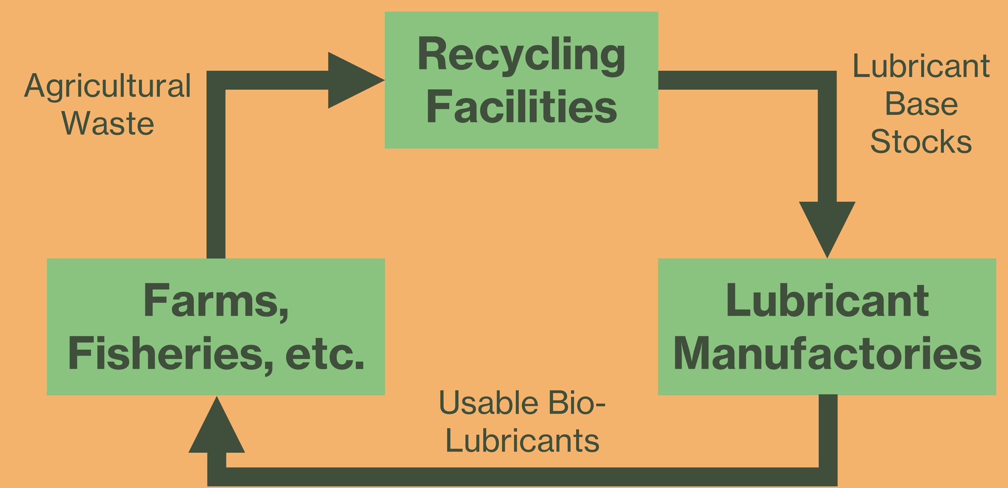


Fig. 1: Bio-lubricant circular economy.

Current Work

Apple-based Lubrication

► Apples *(Malus Domestica)* are cultivated the world over, excluding more tropical regions such as Central Africa and South-East Asia. The waste and non-edibles from apple production provides an opportunity for lubricant formulation without infringing on food supply.

An overview of the method:

- Apple seed solution produced from one 2.73 g Granny Smith seed mixed with 40 ml of deionised water.
- Apple wood solution made from 10 g of clippings immersed in 150 ml of deionised water.
- A PCS High Frequency Reciprocating Rig (HFRR) was used for friction analysis (see Figure 2).
- ISO-12156-1 diesel lubricity standard followed.

Lubrication in Ammonia Engines

► Like their lubricants, the fuels used in most commercial internal combustion engines (ICEs) are also petroleum-based. Researchers at UoB have been experimenting with possible alternatives such as hydrogen [1]. This investigation entails tribological analysis of a conventional engine oil (5W-30) in an ICE using alternative fuelling: currently a gasoline-ammonia-hydrogen blend. Three samples have been studied: unused oil, used oil from a gasoline engine, and used oil from the alternative engine. Test engines were run for 50 hours.

Analysis conducted thus far:

- HFRR friction and optical wear scar analysis as above.
- Surface tension measured using SITA Bubble Tensiometer.
- Viscosity readings obtained with Industrial Physics Viscometer.
- Chemical characterisation performed using Bruker Fourier transform infrared (FTIR) spectrometer.

Geographical Analysis

► Development has begun on a program that extracts and presents countries' trade data from the United Nations Comtrade database. Exported commodities of interest (e.g. bio-lubricant feedstocks) can then be mapped globally, identifying regions where certain lubricants are more feasible than others.

Fig 2: The HFRR (left) and its stainless steel specimens (right) [2].

Results

► Figure 3 shows how the mean coefficient of friction (COF) varied over the duration of the ball-on-disk friction tests, for each of the lubricants examined. The two apple-based lubricants are compared to deionised water and SN100, a common base oil used in the automotive sector.

Fig. 3: Mean COF variation throughout HFRR lubricity test.

Mean of median COFs

Apple seed: **0.365**

Apple wood: **0.316**

Figure 4 shows how the mean surface tension varied for each conventional oil sample with bubble lifetime – the time for an injected air bubble to pop in the liquid.

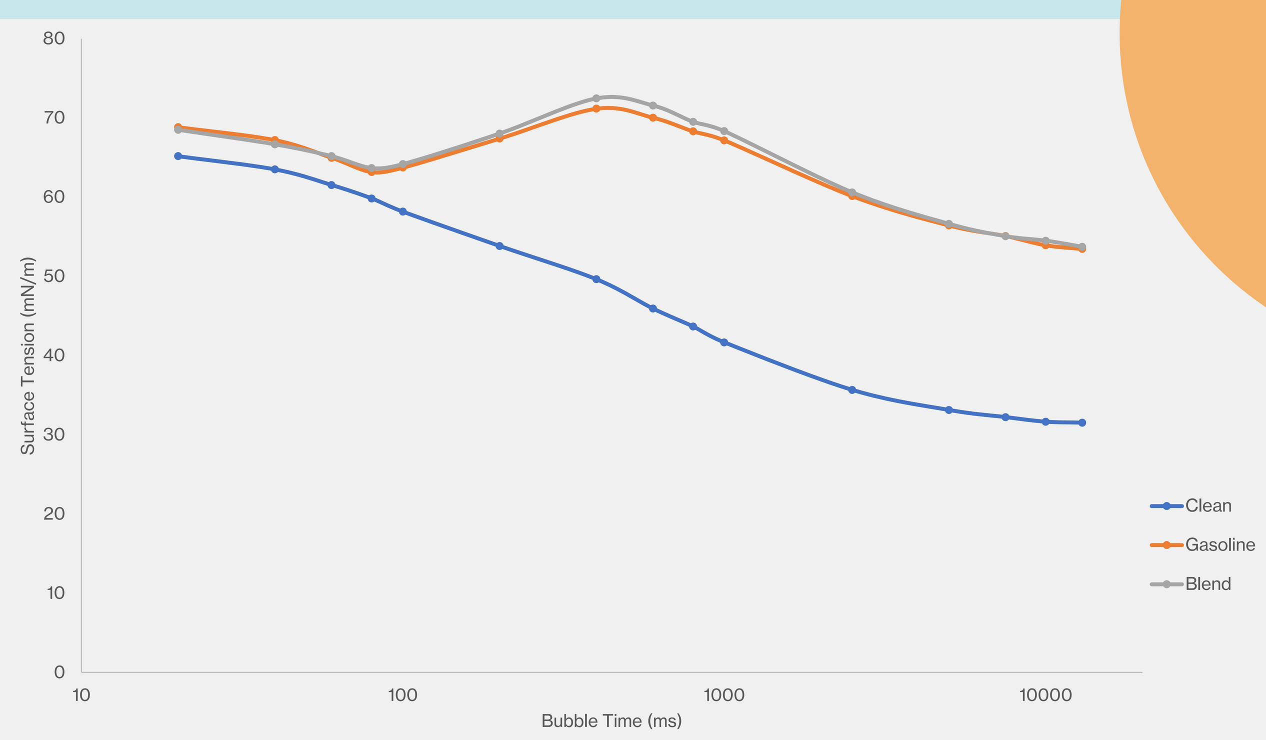
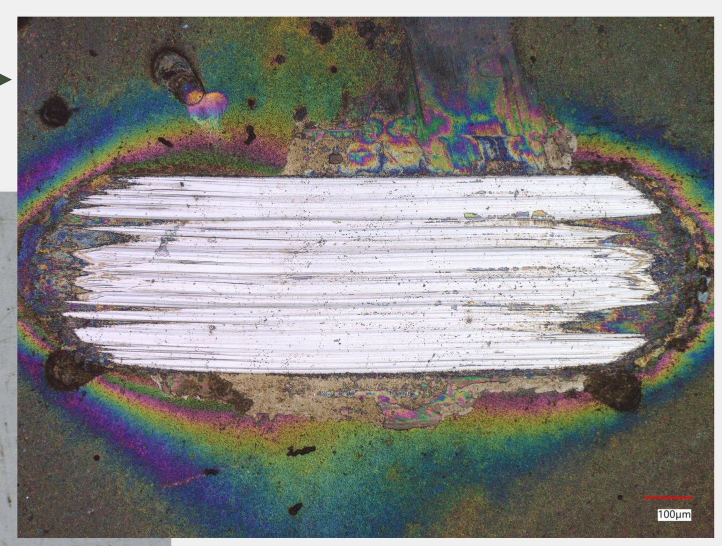
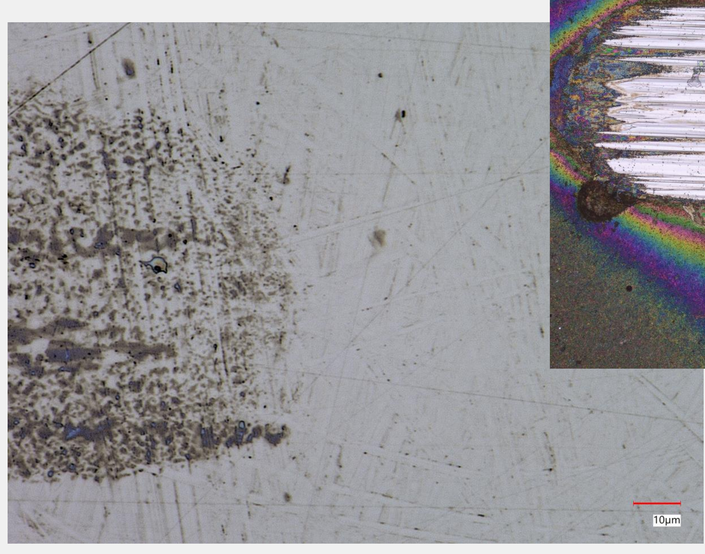


Fig. 4: Mean surface tension readings for each 5W-30 oil sample, over a range of bubble lifetimes.

Fig. 5a: Lower specimen wear scar after a HFRR test using apple wood solution (200x mag.). ►





◄ **Fig. 5b:** Lower specimen wear scar close-up from a 5W-30 oil HFRR test, after washing with degreaser (2000x mag.).

Displayed in Figure 5 are wear scar images obtained optically. Profilometry data was also calculated optically. In the case of Fig. 5a, the area roughness measured at one end of the scar was **Sa = 0.72 µm**, whereas the corresponding value outside the scar was **Sa = 0.41 µm.**

Future Work

Prospective Bio-Lubricants

► After reviewing the literature, presented below are a few materials that, with some chemical modification (e.g. epoxidation, transesterification, etc.), show promise as a bio-lubricant feedstock or base oil.

Potential feedstock candidates:

- Fish slime / mucus and other fishery waste.
- Bagasse – dry, fibrous pulp remaining after juice extraction from plants such as sugarcane and cashew apples.
- (Micro)algae and cyanobacteria.
- Agricultural plastic waste e.g., greenhouse films, irrigation pipes, etc.

Alternative Lubricants, Alternative Combustion

► Following on from the present work analysing the effects ammonia and hydrogen may have on existing engine oils, an opportunity arises to test bio-lubricants developed over the course of this project in conventional and alternative internal combustion engines.

Collaboration with External Institutions

► Building on existing relationships, we are collaborating with other academic institutions working in a similar area to reduce replication and increase the depth of available research.

References

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[2] Instruments, P. (2023, June 1). HFRR. PCS Instruments. https://pcs-instruments.com/product/hfrr/

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