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Novel Sustainable Grease Developed From Waste Cooking Mustard Oil and Garlic Oil: A Study of Rheological and Extreme Pressure Properties

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The rheological and tribological performances of waste cooking oil (WCO)-based novel sustainable grease with garlic oil as an extreme pressure (EP) additive were examined according to the ASTM standards (ASTM D1092 and ASTM D2783) using a four-ball tester. The commercially available lithium-based grease served as a reference grease for comparing and evaluating the rheological and tribological properties of the WCO-based greases. The addition of 6% garlic oil as an EP additive increased the weld load of WCO-based sustainable grease from 1560 N to 2450 N. The average wear scar diameter of WCO-based and WCO + (GO + 6 wt%) grease is reduced by 13.87% and 19.30%, respectively, compared to that of commercial (MIDCO AP-3) grease. Furthermore, the viscosity and shear stress of WCO-based grease increased with higher thickener concentrations, achieving rheological performance comparable to commercial grease. It is envisaged that garlic oil-filled grease with WCO as base oil will not only have good lubricating properties but will also pose minimum environmental hazards.
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Keywords: sustainable grease, garlic oil, waste cooking oil, extreme pressure properties, grease lubrication, lubricants, tribological systems, viscosity, wear

1 Introduction

In recent years, the quest for environmentally friendly lubricants has gained momentum, driven by increasing concerns about resource depletion, waste management, and pollution associated with traditional petroleum-based products [1–3]. Sustainable greases, derived from biodegradable and renewable sources, offer a promising alternative that aligns with global objectives for reducing environmental impact [4]. Waste cooking oils, particularly from plant-based sources like mustard, present an innovative solution by providing a second life to a common waste product, thereby addressing both sustainability and waste reduction goals [5]. Mustard oil, known for its high oxidative stability, has shown potential as a lubricant base, while garlic oil, rich in sulfur-containing compounds, introduces natural extreme pressure (EP) characteristics, making it an attractive additive for enhanced performance in high-stress applications [6,7]. Despite the progress in developing bio-based lubricants, the potential of waste-derived oils remains underexplored, particularly in high-stress applications requiring robust rheological and EP performance. While plant-based oils have been investigated for lubricant formulations, many studies overlook waste cooking oils, which represent an abundant and largely untapped resource [8–11]. Additionally, limited research has focused on the synergistic properties that specific bio-additives, such as garlic oil, could provide to enhance EP characteristics naturally. This gap highlights a need for research into sustainable, high-performance grease formulations that effectively combine waste oils and natural additives, thereby addressing both environmental and functional demands within the lubrication industry.

In the realm of bio-based lubricants, extensive studies have focused on oils such as castor oil, palm oil, soybean oil, and rapeseed oil, all of which are valued for their biodegradability and favorable tribological properties [12–15]. However, the utilization of waste cooking oils (WCOs) represents a more sustainable approach, as it not only replaces virgin oils but also mitigates waste disposal challenges. Comparatively, WCOs have demonstrated competitive oxidative stability and viscosity characteristics, especially when sourced from mustard oil, making them viable candidates for lubricant applications [16]. Furthermore, bio-additives such as graphene offer unique advantages over synthetic EP additives like zinc dialkyl dithiophosphate due to their natural compounds, which provide comparable EP performance while being environmentally benign [17]. This dual approach of recycling waste oils and using plant-derived additives sets the stage for innovation in sustainable lubrication technology.

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