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Extraction of Oil from Fresh and Spent Coffee Extracts from Assorted Geographies

Biofuels from Coffee
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Abstract:- The exponential growth in coffee consumption and the extensive coffeehouse presence in the United States have led to a significant increase in spent coffee waste production. This waste contributes to environmental degradation, particularly in the form of methane emissions in landfills. To address this issue and explore eco-friendly alternatives, this study investigates the oil content in spent coffee grounds (SCG) from different geographical regions as a potential source for biofuel production.

Fifteen diverse coffee samples were collected from various global locations and analyzed for their oil content. Fresh Coffee Grounds (FCG) and Spent Coffee Grounds (SCG) were extracted using isopropyl alcohol, and the oil content was measured gravimetrically. South American coffees from Peru, Colombia, and Brazil exhibited higher oil levels in comparison to other regions.

To improve the quality of extracted oil for biofuel applications, saponification was employed to transform excess triglycerides into glycerol and crude soap, yielding a mixture of fatty acid methyl esters containing oil. Further scaling up the extraction process demonstrated that South American coffee varieties had significantly higher oil levels compared to American coffee.

The findings provide valuable insights for selecting suitable coffee waste sources for biofuel production, especially from high-oil-content South American coffee varieties. Future research may involve detailed chemical composition analysis through GC-MS to identify key fatty acids like linoleic, palmitic, and oleic acid for optimal diesel fuel production. Collaboration with coffee chains to assess their spent coffee waste could pave the way for a practical, environmentally friendly solution, making a compelling economic case for green biofuel.

Keywords:- *Coffee Extracts, Oil Extraction, Spent Coffee Ground, Fresh Coffee Extract, Saponification.*

I. INTRODUCTION

The coffee supply chain and consumption have significantly increased in the last decade. The United States of America has 37189 coffeehouse stores, and they contribute significantly towards the generation of spent coffee waste (1). In 2019-2020, US coffee consumption totaled 1.602 billion kilograms of coffee. Spent coffee waste, the obvious by-product of the coffee-making process, can influence the environment as they land up going to landfills. The waste generated throughout the world is 5.4 billion kg. coffee waste typically goes to landfills and emits lots of methane, which is 34 times more potent than carbon dioxide (2). The oil in the coffee seeps down to the ground and makes the soil acidic, Furthermore, the decomposition of coffee waste generates greenhouse gases such as Methane which is known to be more harmful than carbon dioxide (3). It has been demonstrated by researchers that using four-step chemical reactions it is possible to obtain biofuel from coffee waste (4). The treatment of coffee waste and converting it into biofuels can offer some degree of solution to the problem of greenhouse emissions and declining fossil fuel issues. It will usually emit methane over 100 years. Spent Coffee Grounds (SCG) can be used as starting material for Biodiesel production (5). Reports suggest that transesterification and saponification after oil extraction can help us to obtain mono-alkyl esters of long-chain fatty acids desired state of oil which can be used as Biodiesel (6). Biofuel is a good alternative to fossil fuel but is more expensive. If we can identify a better source of coffee oil, then the process will make economic sense (7). The influence of geographies on coffee depends on the processing and cultivation methods practiced in a region, as well as political and environmental factors. In this project, fifteen different coffee samples were procured from different geographies around the world and analyzed for oil content.

II. MATERIALS AND METHODS

➢ *Fresh and Spent Coffee Ground*

Fifteen different coffee powders were obtained from local grocery stores. The coffee was brewed as per routine brewing methods. Fresh Coffee Grounds (FCG) had on average 50% moisture and were used for the extraction of oil directly. Spent Coffee Grounds (SCG) obtained from brewed coffee were dried using the drying oven method at 105 °C for 24 h. 0.5 g

➢ *Oil Extraction*

0.5 grams of Fresh Coffee Grounds (FCG) and Spent Coffee Grounds (SCG) were subjected to extraction using 5 ml of Antiseptic solution containing Isopropyl Alcohol (90%v/v) in 15 ml tubes. The mixture was heated at 60 °C for 2 h. The samples were filtered and normalized for 5 ml volume and endpoints were measured.

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➢ *Viscosity Measurement*

For viscosity measurements, it was assumed that liquids with low viscosity will flow quickly in comparison to liquids that have a high viscosity flow slowly. The extracted oil was placed in a 100 ml measuring cylinder and a copper penny was dropped from the top. The assumption here was that a more viscous liquid will have more oil. Water, Coconut Oil, and Canola oil were used as a control in triplicates. The time taken by a penny to travel to the bottom of the measuring cylinder was measured in milliseconds.

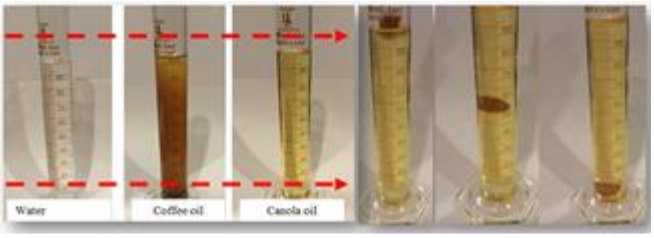

Fig. 1. Viscosity measurement of oil extract from fresh and spent ground extracts obtained from coffee from different geographies for fresh and Spent ground extracts using the Penny drop method. The time taken to travel from top to bottom was used as a measure of viscosity.

➢ *Saponification*

Spent Ground Extracts were subjected to Saponification (n=15) ml tube. The samples were treated with 0.1 M sodium hydroxide. The mixture was heated at 60 °C for 2 h. After treatment samples were filtered and the oil fraction was extracted in hexane. The reaction again was done in a 15 ml tube with 5 ml isopropyl alcohol and 2 ml Hexane. The top layer of hexane (hyper phase) was collected and weighed out. The scaled-up experiment used a separating funnel instead of a 15 ml tube for oil extraction.

III. RESULTS AND DISCUSSION

The extraction of oil using isopropyl alcohol from fresh and spent ground extract suggested that there is wide variation in the oil content in several geographies (Fig. 2.).

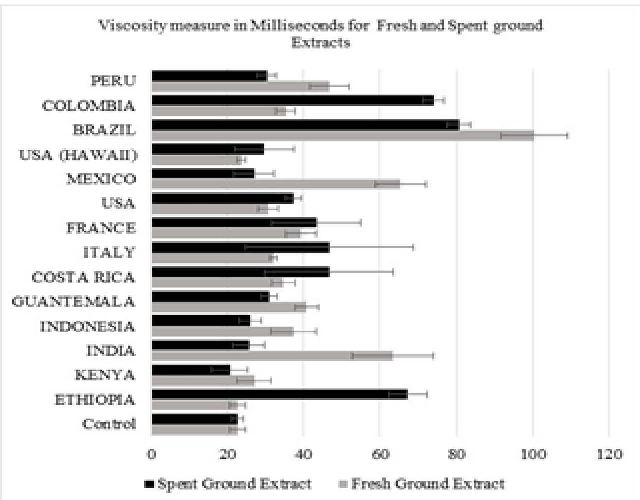

Fig. 2. Change in viscosity of oil extract in saponified fresh and spent ground extracts obtained from coffee from different geographies for fresh and Spent ground extracts.

The solvent-extracted mixture had triglycerides present in the coffee waste. To get rid of these, the mixture was subjected to saponification. Saponification is the process of turning lipids into soaps and alcohol by the addition of heat and alkali. Saponification resulted in the removal of excess triglycerides in the mixture as it got transformed into glycerol and crude soap as obtained in the aqueous fraction. Since glycerol and soap are water-soluble, we got a mixture of fatty acid methyl esters containing oil and an aqueous solution of excess by-products. The stable emulsions formed during the process were broken down using saturated sodium chloride. After washing off the alkali from the oil multiple times, the oil fraction was weighed for all geographical SCG.

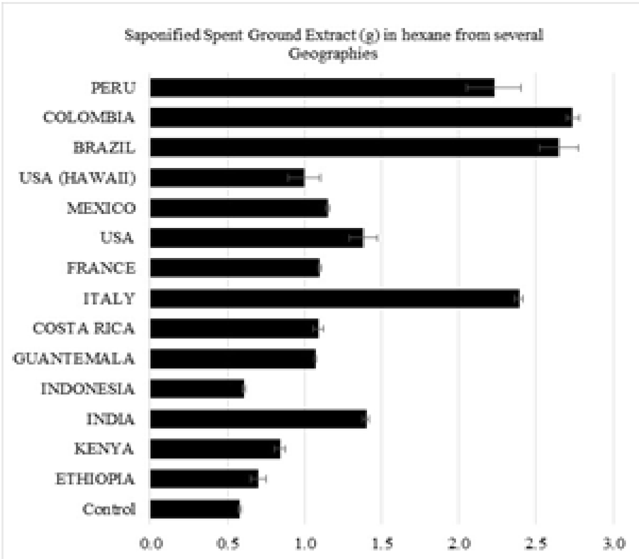

Fig. 3. Oil content in 0.5 g of Saponified Spent ground Extract in 2 ml of hexane. South American coffees (Peru, Colombia, Brazil) traditionally had higher levels of oil in them in comparison to coffees from other world geographies.

Based on the results shown in Fig. 3, Scaled extraction was conducted in a separating funnel (Fig. 4. & Fig. 5.) for selected varieties (Brazil and USA). The scaled-up experiment suggests that a variety from Brazil had higher [16-29 %] levels of oil in comparison to American coffee [5-6%].

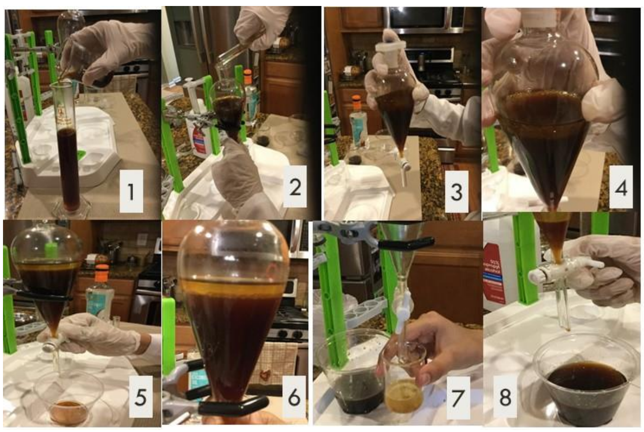

Fig. 4. Scaled-up extraction of oil from Spent Ground Extracts. 1-3: Addition of hexane to washed saponified oil in separating funnel; 4-6: Shaking after addition of saturated

salt solution to break emulsion; 7-8: Collection of oil fraction for endpoint measurements.

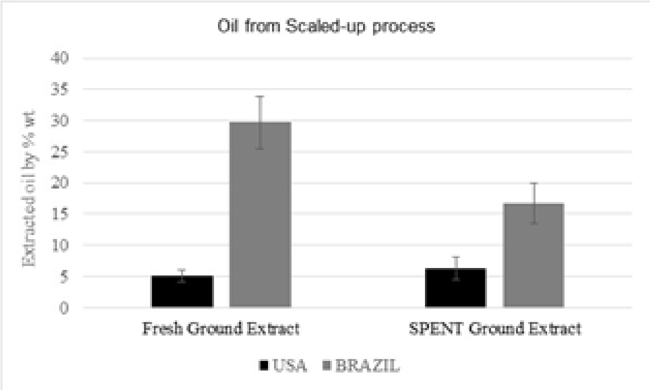

Fig. 5. Scaled-up extraction of oil from two selected geographical varieties (Brazilian and American); The Extracted oil levels from Brazilian Coffee Extracts were very high in comparison to American coffee.

CONCLUSIONS

In this project, fifteen different coffee varieties from different geographies were screened for oil levels in Spend Coffee Ground for potential use in making biofuels. Initial screening was done using both Fresh and Spent ground extracts and their saponified and unsaponified extracts. Among all geographies studied, South American coffee from Peru, Colombia, and Brazil had the highest levels of extractable oil. This work will help in picking up the right variety of spent coffee extract for biofuel production as a high level of Biofuels from the spent ground extract can help us to make an economic case for green biofuel. This work measures oil gravimetrically, as a next step, it will be nice to perform further deep-down GC MS analysis on samples to get the exact chemical composition of oil fraction. We obtained 15-16% oil from coffee waste. It will be good to have an oil fraction dominated by fatty acids such as linoleic, palmitic, and oleic acid whose carbon length suits the production of diesel fuel. As a next step, it will be helpful to work with some of the coffee chains and test their spent coffee waste for testing oil levels.

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