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Coffee as an Alternate Fuel

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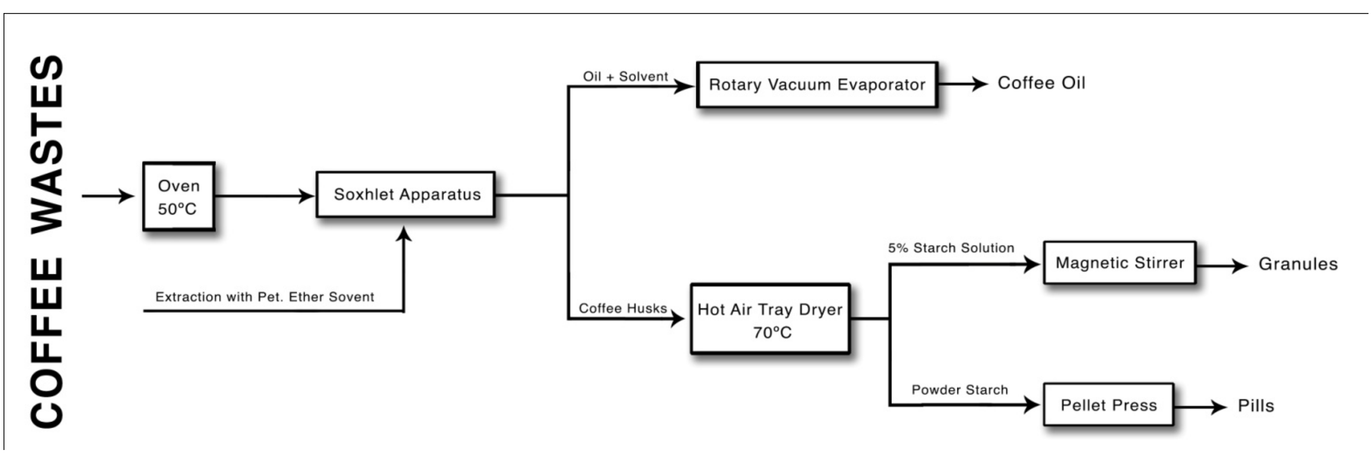
Abstract—*With the formation of stringent environment laws created to tackle climate change, it is imperative that new forms of sustainable fuels are synthesized to meet the ever increasing demand. About 400 kg of wet waste pulp is produced from 1000 kg of fresh berry. The wet pulp of the coffee contains caffeine, tannins, polyphenols and organic solid residues. The prototype demonstrates a form of sustainable energy wherein coffee husk generated are turned into an alternate source of 'green' fuel. Our prototype converts these husks into a biofuel in the form of oil and pellets. The aim of this study is to investigate the potential of achieving zero waste by using waste coffee grounds for biofuel production by extracting the oil and utilizing the leftover waste for pelletization. However, biofuel production is a fairly expensive process with its feedstock comprising the major cost. For this reason the investigation for new attractive alternative feedstock is important. The aim of this study was to demonstrate the utilization of waste coffee grounds as a potential new-low cost alternative feedstock for biofuel production. For this study, leftover coffee grounds were collected from neighboring coffee shops. Moreover, the biodiesel derived from coffee oil possesses better oxidation stability than biodiesel from other sources, due to the endogenous antioxidants it contains. In addition, the waste solid remaining after the oil extraction can be utilized as compost or can be pelletized (as in this paper). This study has offered a new perspective in the field of biofuels.*

1. INTRODUCTION

A biofuel is produced through contemporary biological processes of carbon fixation that occur in plants or microalgae due to photosynthesis. Carbon fixation takes inorganic carbon and converts it into organic compounds.

The concept of biofuels is as old as the concept of cars. At the start of the 20th century, Henry Ford planned to fuel his Model T with ethanol. Early diesel engines were designed to run on peanut oil [1]. Biofuel can be used as a fuel for vehicles in its pure oil form, however it is usually used as a diesel blend to reduce levels of carbon monoxide and hydrocarbons in diesel-powered vehicles. Biofuel produce lesser greenhouse gasses than fossil fuels, reduce emission of any particulate matter, such as soot or other fine particles, and allows greater fuel security for countries with little or no oil reserves of their own.

The use of coffee as a biofuel raises some serious concerns over the "Fuel verses Food" thought, however, spent coffee grounds eliminates the need to bring new land under cultivation and does not necessarily detract from the conventional process of producing food. Extracting oil from waste grounds can practically diminish the cost of feedstock. This balance between food and biofuel keeps the relatively simple process of growing and producing biofuels substantially economic than fossil fuel.



Coffee waste contains up to 20 percent oil per unit weight, which is quite in the range of biodiesel feedstock currently used, such as rapeseed and soybean. Coffee-derived biofuel can potentially add 343 million gallons of fuel to current stock which accounts for less than 1 percent of global fuel production [2].

The pellets in this study are produced as two different forms: pills and granules. The flavor and smell of the coffee is due to the presence of the oil in its beans. Oil extracted have the typical characteristics of dark brown colour and a rich coffee aroma, hence pellets produced by this process do not give the rich coffee scent when burnt. Various coffee samples have not shown a vast difference in in any of the relevant physical properties of the oil or the amount of oil obtained [3].

Coffee biofuel reduces the amount of nitrogen present in caffeine's chemical composition which is undesirable as it can lead to elevated production of mono-nitrogen oxides, a greenhouse gas [4]. Additional advantages of this biofuel are low caffeine contents and high antioxidant properties.

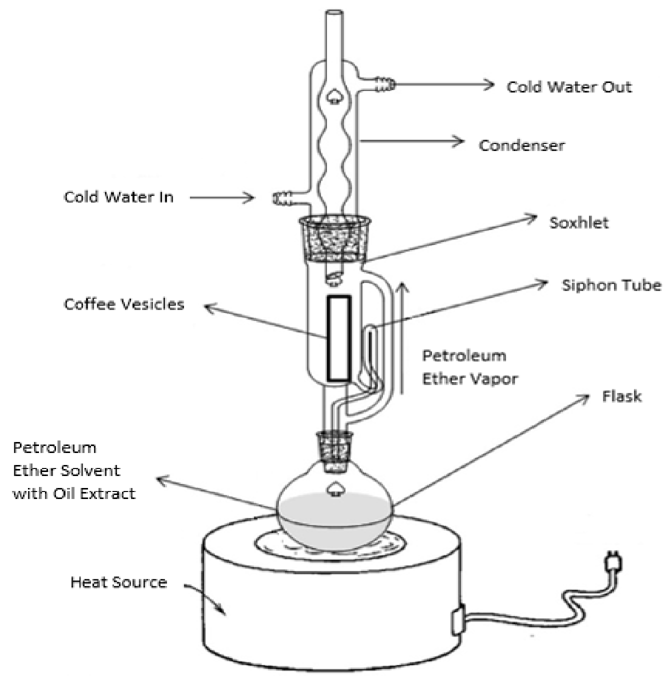
Surveys show a worldwide biofuel production of 105 billion liters in the year 2010, which is an increase of almost 17% since 2009. Biofuel have provided 2.7% of the world's fuels for road transport [5]. According to the United States Department of Agriculture, the world's coffee production is 16.34 billion pounds per year. India has emerged as the seventh largest coffee producer in the world at 4.05% of global coffee production. India exports coffee to over 45 countries growing at a rate of 11.05% [6].

2. EXPERIMENTAL

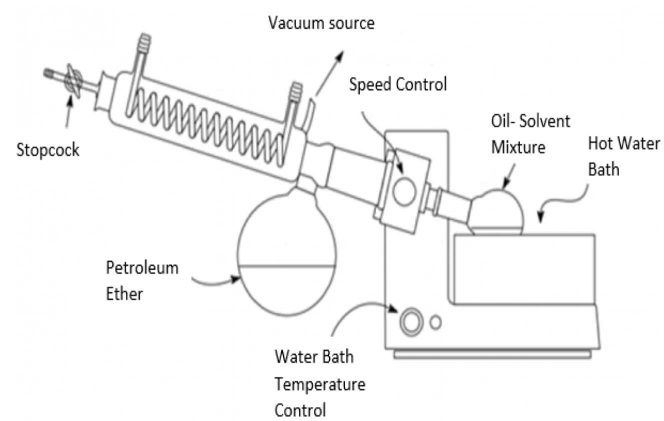
2.1 Oil Extraction

For the process of extraction of oil, used coffee grounds were purchased from a local coffee house. These grounds were dried in an oven operated for an hour at high temperature (~50° C) till the grounds are completely dried. It is important to remove the water because presence of water reduces the conversion of triglycerides to fuel and to meet the standards for commercialization. The sample was tested for its compressibility index to investigate its pelletization properties. Compressibility index was found out to be 9.04%.

Soxhlet apparatus was prepared for extraction of coffee oil. Solvent used was petroleum ether (boiling range 40°C to 50°C). The grounds were weighed and added into semi permeable vesicles (1 gram of sample + 5 ml solvent). 200 gram of dried coffee powder was taken in parts and filled in vesicles made of muslin cloth or starch paper. The vesicles are placed in a soxhlet apparatus for 5-7 hours with petroleum ether. These packets were put in the Soxhlet apparatus with above solvent. The soxhlet apparatus setup is shown in *Figure 2*.



The mixture of the solvent and oil from the extraction apparatus is then separated using a rotary vacuum evaporator. The petroleum ether is evaporated, condensed by the action of cooling water and collected separately. It can be reused. The concentrated form of extracted oil is left behind in the flask. The setup can be seen in *Figure 3*.



2.2 Pelletization

The husks of coffee husks are collected from the soxhlet apparatus after the oil extraction process. These waste coffee was dried in the hot air tray dryer at 70° C for 3-4 hours to remove moisture and leftover solvent. These dry coffee grounds were sieved for free flow and fine powder, using a sieve shaker.

Dried coffee husks were further separated in two halves where one half was used to form pellets in the form of pills and the other half was used to form granules.

2.2.1. Formation of Pills. The mixture of the husks combined with the binder, corn starch (insoluble, laboratory grade) where the coffee and starch ratio is 2:1. They are added into a - pellet press - and made into pellets. These pellets can be used as a biofuel.

2.2.2. Formation of Granules. For binder, 5% starch solution was used i.e. about 200 ml of water with 10 gram of starch (insoluble, laboratory grade). The starch solution was mixed with the help of a magnetic stirrer (with hot plate) at 30 rpm to form a homogenous mixture. The solution was used to bind the fine coffee powder (in 1:2 ratio) by making soft dough. It was then sieved (using Sieve size 8) for making granules. Granules were dried in an oven at about 83°C for 20-30 minutes to further harden it.

3. RESULTS AND DISCUSSIONS

3.1 Oil Content in Coffee Grounds

Extraction of oil from spent coffee grounds was carried out using the solvent petroleum ether under reflux conditions. The oil extracted (*Figure 4*) was 30 ml for 200 gram of the coffee sample.

The solvent recovery was high (89%) and with proper measures can be as high as 99.9%. The extraction time was lower when muslin cloth with used compared to starch paper. The oil yield was higher in the case of muslin cloth.

The oil content of spent grounds coffee contained 15% on dry weight basis [7]. This results in relatively lower operating costs compared to some other oilseeds such as soybeans, olive and cotton seeds, which have average oil contents of only 20%, 17% and 14%, respectively [8].

3.2 Coffee Oil Properties

Coffee oil was tested to determine its physiochemical properties to be utilized as biofuel. The standard values and the results obtained are summarized in Table 1.

Properties	Units	Limits	Result
Density (15° C)	g/cm3	0.86 - 0.90	0.8505
Kinematic Viscosity (40° C)	mm2/s	2.5 – 6.0	6.6075
Saponification value	mgKOH/g	---	274.4

As biofuel is made up of a small number of methyl or ethyl esters that have very similar densities, the density varies within tight limits [9]. The density of the oil extracted was calculated using a specify gravity bottle. The density of the oil is within the range, so can be used directly as fuel.

The viscosity of the oil, calculated using the viscometer, is slightly high to be used in direct combustion engines. High viscous fuel will interrupt the combustion reaction and lead to the formation of blue smoke. It will also increase the need of fuel pumping energy and cause operational problems at low temperatures [10].

The experiment of saponification showed that the value was too high to be directly converted into biodiesel without pretreatment, which may indicate a higher degree of oxidation and occurrence of hydrolysis reactions [11].

3.3 Pellet Fuel

The coffee grounds are composed of 13.8% cellulose, 36.7% hemicelluloses, 13.6% proteins and 33.6% lignin. Cellulose is a vital source of volatile content in the biomass, while lignin acts as a natural binder in the biomass [12]. Although the grounds contain relatively high lignin content, it is not enough to hold the particles together and form a firm mass.

The finished pellets (*Figure 5*) was heated in the oven at 70°C for 20-30 minutes to remove moisture and avoid the breakage at the slightest pressure.

The calorific value of the pills and granules were calculated using the bomb calorimeter. Both the pellets have a calorific value of 12.3 MJ / Kg. This fuel pellet has a calorific value comparable to the biomass energy obtained from groundnut (12.60 MJ/Kg) [13], cowpea (14.37 MJ/Kg) and soybeans (12.94 MJ/Kg) [14]. The combustion qualities of the fuel produced in this study is sufficient enough to produce the required heat for domestic cooking and also for industrial application such as the energy requirement of the small-scale industries.

4. CONCLUSION

This experiment has demonstrated a method to convert dispensable coffee wastes into viable fuels. The oil and pellets generated create a zero waste system where every part of the coffee has been utilized without changing the conventional techniques of utilizing coffee. With the rising demand of searching for alternate biofuels, our experiment demonstrates one such method. The oil obtained gives a strong coffee aroma and generates little to no fumes. The analysis of the physiochemical properties of the oil proves that, with further modification, it can be directly used as an additive in the combustion engine. The pellets generated by this method can be used as a substitute to many fossil fuels which normally generate fumes.

5. ACKNOWLEDGEMENTS

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