Potential Reuse of Waste Coffee

This article considers the potential for the waste byproduct of one of the world’s most popular beverages—used coffee grounds—to be diverted from landfills and repurposed as an oil basis for biodiesel fuel, a purification material, and an alternative energy source.
Coffee is one of the most popular beverages in the world. Each day, more than 2.25 billion cups of coffee are consumed globally. In the United States, the average coffee consumption in 2008 was 24.2 gallons per person. Although there are more than 70 coffee species, the current coffee market is dominated by two types of coffee species: Arabica and Robusta. The preparation of commercial coffee products starts with processing coffee cherries, the raw fruit of coffee plant, into green coffee beans. The next step is roasting that converts green beans into brown beans. Roasting process gives the characteristic aroma and flavor to the coffee brew, which is dependent on the temperature and retention time of the roasting process.

**WCG Inventory, Properties, and Current Uses**

Coffee consumption leads to the generation of waste coffee grounds (WCG). Accordingly to the International Coffee Organization (www.ico.org), in 2010, the net coffee consumption (both roast and instant) by the United States was 1.31 million tons (2.61 billion lbs). The market share for roast coffee is estimated at 80%. Therefore, the WCG generated in the United States is estimated at 1.05 million tons (2.10 billion lbs) per year. This significant amount of WCG generation every year results in multiple environmental and ecological concerns, such as landfill expansion, and water and soil quality deterioration due to leachate.

The composition of WCG is mainly constituted by cellulose, hemicelluloses, minerals, sugars, oils, polyphenols, and ashes. Concentration and composition of oil in WCG have been explored by several studies. In most cases, oil concentration ranges from 10–20 wt%. It is reported that the oil content in the coffee bean changes negligibly during the roasting and brewing processes and it is reasonable to assume that the oil concentration in the WCG remains close to that of the original coffee cherries. Besides, the composition studies also show that oil from WCG mainly consists of long oxygenated carbon chains, such as C16:0, C18:0, C18:1, and C18:2. Elemental analysis shows that WCG contains mainly carbon (C), oxygen (O), and hydrogen (H), with minor portions of sulfur (S), phosphorus (P), and potassium (K). The size of the WCG varies with different grinding processes and its structure is porous by nature.

Currently, most of the WCG from cafeteria, restaurants, and households are discarded and end up in landfills. Several pathways of direct reuse have been advocated for the reuse of WCG in daily life, such as odor and pest control media, gardening and composting materials, and furniture care (scratch cover). Using WCG as the growth media for certain types of fungi is another alternative of interest. Considering its porous nature, WCG has been studied as the substrate for activated carbon (AC) preparation and tested for removal of various chemicals and pollutants.

**WCG Applications in the Biodiesel Industry**

The composition of the oil in WCG has attracted interest from researchers to find a use for it in the biodiesel field. This application, once commercialized, has the potential to reuse WCG in large quantities, considering the huge biodiesel production...
Grounds after extraction) to bring revenue to the entire supply chain.

One option for the after-extraction WCG is to be used as biodiesel purification material. Biodiesel purification is shifting away from the traditional water wash to “dry wash” approaches, which eliminate water consumption and wastewater generation. Adsorbents and ion-exchange resins have been applied by many biodiesel producers. Depending on the process and the quality of crude biodiesel, the dry wash can cost the biodiesel producer anywhere from 10 cents to 50 cents per gallon of biodiesel.  

From our preliminary study, the after-extract WCG demonstrated comparable purification capability to existing commercial products, which indicates the possibility of reducing costs by applying WCG for purification purposes after its usage in biodiesel production. The replacement of commercial purification materials with WCG can reduce the overall production costs of biodiesel and also lower the

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waste disposal expenses, since it can be burned as adjunct fuel afterward instead of being sent to a landfill, which is the normal practice for the commercial purification materials after use.\(^\text{18}\)

It was found from our preliminary experimentation that WCG possessed a heating value of 8,795 Btu/lb. WCG has also been tested as the alternative fuel at a power plant in Japan.\(^\text{19}\) The results from a life cycle assessment study on burning WCG as solid biomass substrate also showed that combustion of 1 kg of WCG in municipal incinerator can generate 0.53 kWh electricity and 3.92 MJ of useful heat.\(^\text{20}\) So, considering its energy potential, WCG can also serve as a cost-saving option for power generation after it accomplishes its roles as oil source and purification material.

One of the major challenges is how to collect the WCG from individual homes and stores. For WCG to achieve its full potential as an alternative energy source, the separation of WCG from the rest of landfill wastes and educating the public on its possible uses will be necessary.

**Summary**

As one of the world’s most consumed beverages, the prosperity of the coffee industry leaves behind a significant amount of WCG every year. The traditional disposal of WCG into landfills should be revisited. Considering the properties of WCG, it is possible to include it into the biodiesel industry by extracting the coffee oil and making it into biodiesel. Using after-extraction WCG as a purification material and an adjunct fuel may then reduce the overall cost of WCG-derived biodiesel. Although most of the activities in this reuse pathway are still at the research and development stage, the technology development and the increased awareness of sustainability are expected to boost the commercialization of the research outcomes in the near future.

**References**