PRODUCTION OF BIOFUEL FROM USED COFFEE GROUNDS

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Research Café
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How Do You Heat Your Home?

- Natural Gas
- Electricity
- Steam
- Oil
- Geothermal
- Woodstove – type of fuel?

Firewood Alternatives

Woodstoves, Pellet Stoves, Airtight Woodstoves, Fireplaces, Barbecues, Firepits

- **Natural wood**: Douglas Fir, Alder, Maple… Plentiful in Canada.

- drawbacks: smoke, incomplete combustion, ash

- **Artificial Logs**: “Duraflame”(composed of sawdust, paraffin wax)

- Cleaner burn than wood, more expensive

- **Compressed Used Coffee Grounds**: recycled waste coffee grounds

“Bio-Bean Logs (available in the UK)

Pine Mountain “Java Logs” : 2003 Invention of the Year.

Drawbacks: High heat, warning – not to be used in airtight woodstoves!

Questions for our Research

- Can we Test the Heat Content of Used Coffee Grounds in our Labs?
- How do They Compare to Wood?
- Can we Mold the Coffee Grounds into a Smaller, Safer Form?

Some Facts on Coffee Grounds

- Canadian Coffee Consumption: 14.33 lbs/capita (Aug. 2020), 10th in the world
- Each Espresso drink produces 25 grams of waste coffee grounds
- Coffee Grounds contain approx. 20 MJ/kg of heat (Acta, 2016) compared to an average of 16 MJ/kg for wood
- **25% more heat from coffee!**

First Study (Rachel Francis, Douglas College Business Student)

- “Coffee to Biofuels” Jan. 2019
- Expressed need for collaboration with Chemistry students to test heat content of coffee
- Spent Coffee Grounds were donated by **JJ Bean Coffee Roasters,** 3010 Main St. Vancouver. Could their waste coffee grounds be used in their own fireplace?
- First experiments performed by Chem. 1210 student volunteers: results showed promise, but needed refining
- Work was presented at Widemann Prize Competition, April 2019

COFFEE TO BIOFUEL
SAVE THE WORLD WE LIVE IN.

HOW WE CAN TURN COFFEE GROUNDS FROM HARMING OUR WORLD TO SAVING OUR WORLD

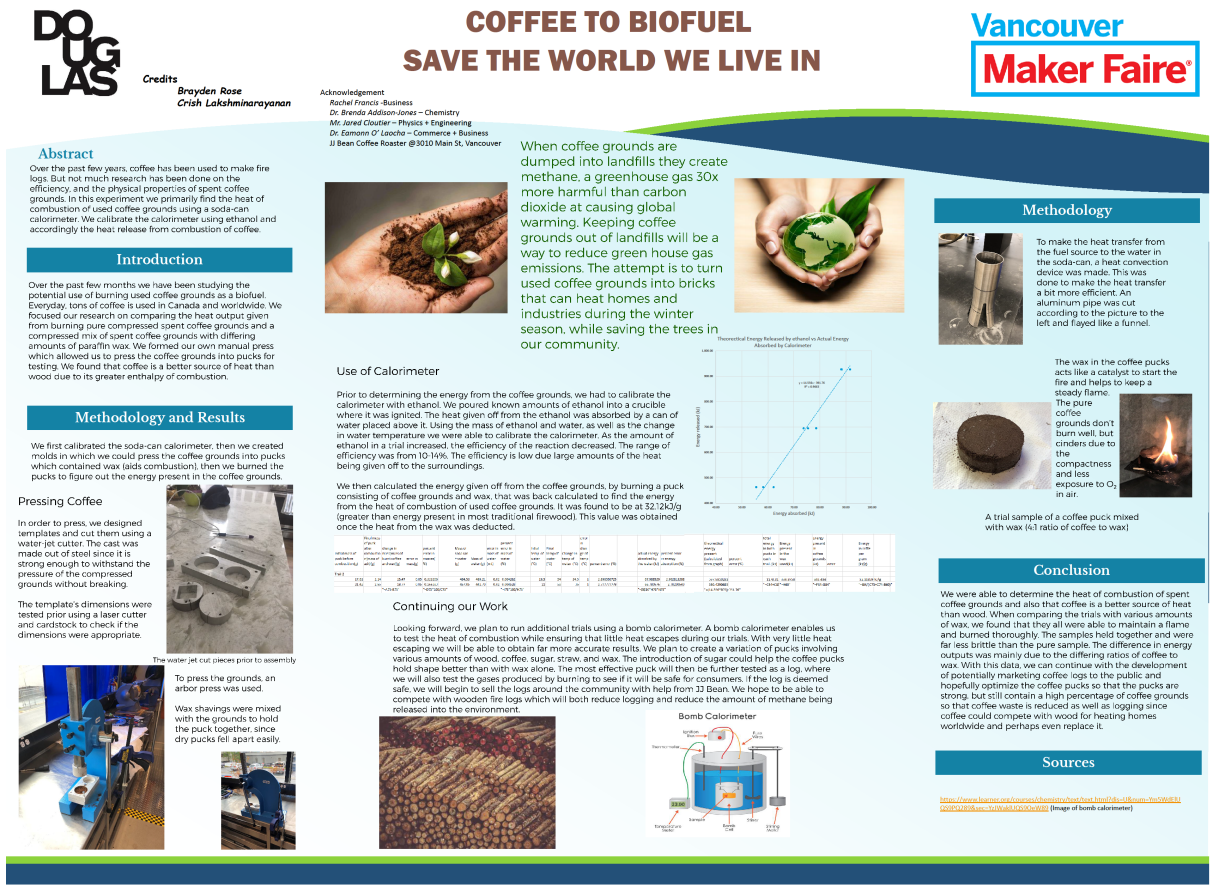
When coffee grounds are dumped into landfills they create methane, a greenhouse gas more harmful than carbon dioxide casing global warming. Keeping coffee grounds out of landfills will be a way to reduce gas emissions. The attempt is to turn coffee grounds into coffee bricks that can heat homes and industries during the winter season, while saving our trees in the community.

SAMPLE	Average Exp'tal Heat of Combustion (J/g)	True (Corrected) Heat of Combustion (J/g)
MARSHMALLOW	3920 ± 80	14000
WOOD SHAVINGS	8760	31300
COFFEE WITH 25% PARAFFIN WAX	12100	43200
COFFEE GROUNDS WITHOUT HEAT FROM PARAFFIN	12200	43600

Research Incentive Grant (Spring, 2019)
B. Addison-Jones (Chemistry), Eamonn O'Laocha (Commerce and Business Administration)

- 2 Student Research Assistants hired to produce "Coffee Pucks" and perform calorimetry experiments:
- Crish Kannan Lakshminarayanan
- Brayden Rose
- Coffee grounds were processed into a hockey puck shape using CADD designing, prototyping, and pressing in our Engineering Lab, with the Assistance of Jared Cloutier
- Results Presented as a Poster at Science World ***Maker Faire***, Sept. 2019
- Douglas College Blog Report, "Grounds for Change", Feb. 2020
- https://blog.douglascollege.ca/2020/02/26/instructor-turns-coffee-waste-into-biofuel/

Maker Faire Poster



DOUGLAS

Credits
Brayden Rose
Crish Lakshminarayanan

COFFEE TO BIOFUEL
SAVE THE WORLD WE LIVE IN

Vancouver Maker Faire

Acknowledgement
Rachel Francis -Business
Dr. Brenda Addison-Jones – Chemistry
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Dr. Eamonn O' Leocha – Commerce + Business
JJ Bean Coffee Roaster @3010 Main St, Vancouver

Abstract
Over the past few years, coffee has been used to make fire logs. But not much research has been done on the efficiency, and the physical properties of spent coffee grounds. In this experiment we primarily find the heat of combustion of used coffee grounds using a soda-can calorimeter. We calibrate the calorimeter using ethanol and accordingly the heat release from combustion of coffee.

Introduction
Over the past few months we have been studying the potential use of burning used coffee grounds as a biofuel. Everyday, tons of coffee is used in Canada and worldwide. We focused our research on comparing the heat output given from burning pure compressed spent coffee grounds and a compressed mix of spent coffee grounds with differing amounts of paraffin wax. We formed our own manual press which allowed us to press the coffee grounds into pucks for testing. We found that coffee is a better source of heat than wood due to its greater enthalpy of combustion.

Methodology and Results
We first calibrated the soda-can calorimeter, then we created molds in which we could press the coffee grounds into pucks which contained wax (aids combustion), then we burned the pucks to figure out the energy present in the coffee grounds.

Pressing Coffee
In order to press, we designed templates and cut them using a water-jet cutter. The cast was made out of steel since it is strong enough to withstand the pressure of the compressed grounds without breaking.

The template's dimensions were tested prior using a laser cutter and cardstock to check if the dimensions were appropriate.

The water jet cut pieces prior to assembly

To press the grounds, an arbor press was used.

Wax shavings were mixed with the grounds to hold the puck together, since dry pucks fell apart easily.

When coffee grounds are dumped into landfills they create methane, a greenhouse gas 30x more harmful than carbon dioxide at causing global warming. Keeping coffee grounds out of landfills will be a way to reduce green house gas emissions. The attempt is to turn used coffee grounds into bricks that can heat homes and industries during the winter season, while saving the trees in our community.

Use of Calorimeter
Prior to determining the energy from the coffee grounds, we had to calibrate the calorimeter with ethanol. We poured known amounts of ethanol into a crucible where it was ignited. The heat given off from the ethanol was absorbed by a can of water placed above it. Using the mass of ethanol and water, as well as the change in water temperature we were able to calibrate the calorimeter. As the amount of ethanol in a trial increased, the efficiency of the reaction decreased. The range of efficiency was from 10-14%. The efficiency is low due large amounts of the heat being given off to the surroundings.

We then calculated the energy given off from the coffee grounds, by burning a puck consisting of coffee grounds and wax, that was back calculated to find the energy from the heat of combustion of used coffee grounds. It was found to be at 32.12kJ/g (greater than energy present in most traditional firewood). This value was obtained once the heat from the wax was deducted.

Continuing our Work
Looking forward, we plan to run additional trials using a bomb calorimeter. A bomb calorimeter enables us to test the heat of combustion while ensuring that little heat escapes during our trials. With very little heat escaping we will be able to obtain far more accurate results. We plan to create a variation of pucks involving various amounts of wood, coffee, sugar, straw, and wax. The introduction of sugar could help the coffee pucks hold shape better than with wax alone. The most effective puck will then be further tested as a log, where we will also test the gases produced by burning to see if it will be safe for consumers. If the log is deemed safe, we will begin to sell the logs around the community with help from JJ Bean. We hope to be able to compete with wooden fire logs which will both reduce logging and reduce the amount of methane being released into the environment.

Bomb Calorimeter

Methodology
To make the heat transfer from the fuel source to the water in the soda-can, a heat convection device was made. This was done to make the heat transfer a bit more efficient. An aluminum pipe was cut according to the picture to the left and flayed like a funnel.

The wax in the coffee pucks acts like a catalyst to start the fire and helps to keep a steady flame. The pure coffee grounds don't burn well, but cinders due to the compactness and less exposure to O_2 in air.

A trial sample of a coffee puck mixed with wax (4:1 ratio of coffee to wax)

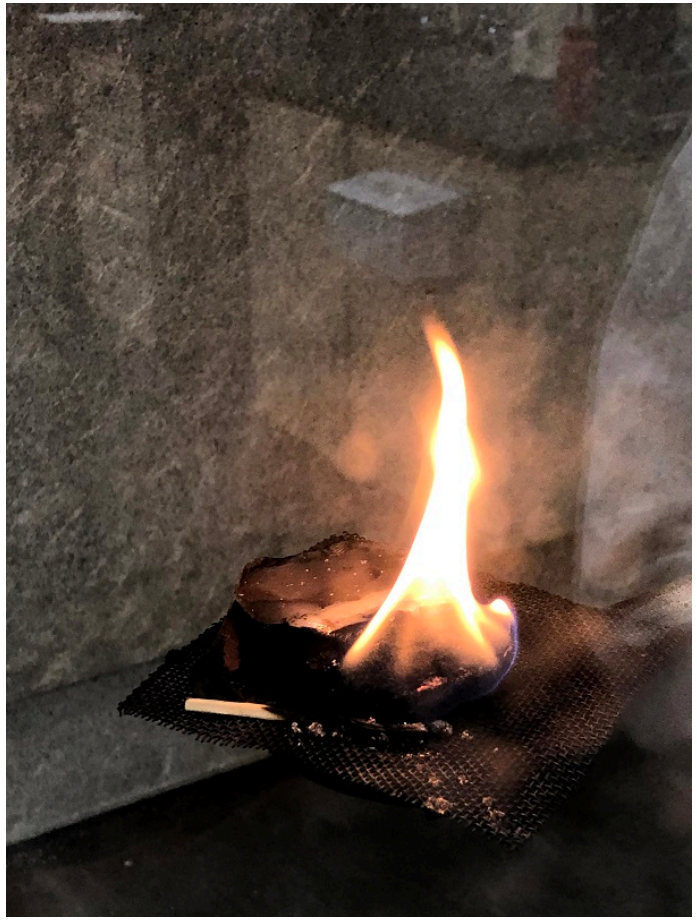
Conclusion
We were able to determine the heat of combustion of spent coffee grounds and also that coffee is a better source of heat than wood. When comparing the trials with various amounts of wax, we found that they all were able to maintain a flame and burned thoroughly. The samples held together and were far less brittle than the pure sample. The difference in energy outputs was mainly due to the differing ratios of coffee to wax. With this data, we can continue with the development of potentially marketing coffee logs to the public and hopefully optimize the coffee pucks so that the pucks are strong, but still contain a high percentage of coffee grounds so that coffee waste is reduced as well as logging since coffee could compete with wood for heating homes worldwide and perhaps even replace it.

Sources
https://www.learner.org/courses/chemistry/text/text.html?ids=10&sum=Yes (Image of bomb calorimeter)

Coffee Press

Coffee Puck

Coffee on Fire



Pop Can Calorimetry

Improved Results: Use of Bomb Calorimeter

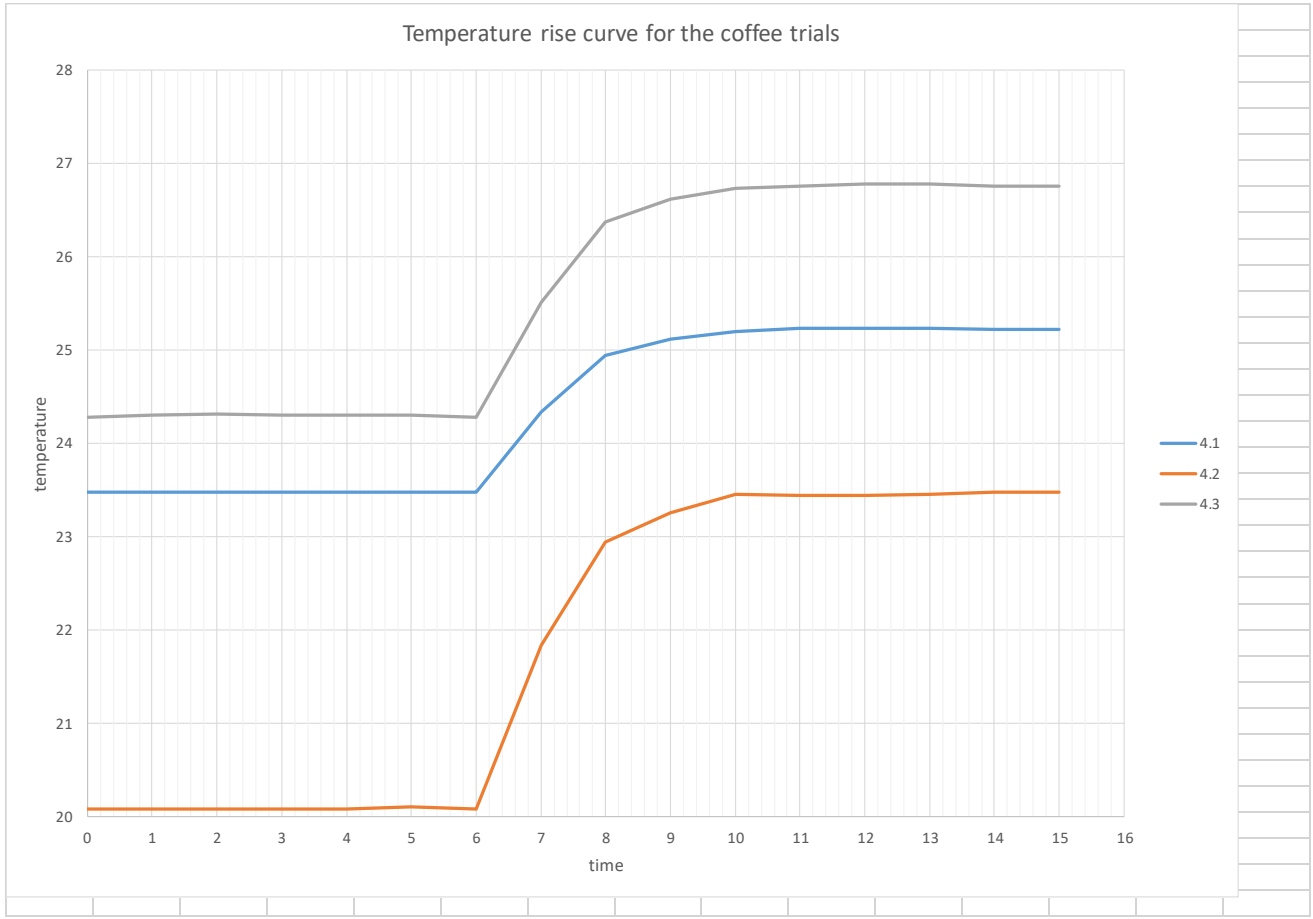
- A Bomb Calorimeter is standard apparatus used to measure the total heat content of substances, such as food
- Theory and Technique taught in Chem. 1210. Bomb Calorimetry is a classic Thermochemistry Experiment for Chemistry Students
- Little heat loss: heat generated by sample is contained and transferred to surrounding water jacket.

Parr Bomb Calorimeter

The Bomb is connected to a cylinder of O_2 Gas

The “Bomb” : charged with 30 atm Oxygen

Bomb Calorimeter Results for Combustion of Coffee Grounds



Further Work: Winter 2021

- Repeat Bomb Calorimeter Results with Improved Oxygen Regulator
- Recalibrate Device
- Perform Trials with Varying Amounts and Types of Catalyst (Paraffin, Beeswax, Pure Coffee)
- Explore New Coffee Puck Designs
- ***RECALL COFFEE CONSUMPTION STATS:***

“Based on average coffee consumption in Canada, coffee grounds could provide 31,000 kcals of energy per capita annually.

Acknowledgements

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  Rachel Francis

  Crish Kannan

  Brayden Rose

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