Flamin' Hot Biofuel

Suggested Grade Level: 6-8

Time: 90 minutes

Subject: Science, Chemistry, Energy Transfer, Matter Interactions, Language Arts, Research, Math, Algebraic Expressions, Proportional Relationships, Measurement, Agriculture, Sustainable Agriculture

Overview: Soybeans are a significant component of biodiesel production in the U.S. This lab allows students to compare the amount of energy produced by soybeans and other biomass. Students will follow an experiment outline to investigate how biomass can be converted into a biofuel. They will burn a Cheeto, wood, a peanut, or dried algae to see how much energy they can produce. There is an optional lesson, highlighted below, that can be used before this lesson to provide more background to the students.

Objectives:

1. Demonstrate how to utilize soybeans as a source of energy.
2. Explain how energy from soybeans and other plants creates fuel.
3. Describe the need for soybeans and other biomass to create biodiesel fuel for the future.

Background Information:

In the 2023–2024 marketing year, the United States produced an impressive 27.1 billion pounds of soybean oil (The). This oil comes from crushing soybeans, with each bushel yielding over 10 pounds. Soybean oil is a vital ingredient in a wide array of everyday products and industrial applications. Industries currently use soybeans to manufacture items such as printing ink, crayons, lecithin found in cooking spray and chocolate, biodiesel fuel, vegetable oil, and even building materials used in countertops and flooring. It is also an ingredient in infant formula, showcasing its versatility across both industrial and consumer markets.

A significant and growing use for soybean oil is in the production of biodiesel—a renewable, clean-burning diesel replacement that significantly reduces greenhouse gas emissions. According to the U.S. Department of Energy, biodiesel fuel can reduce greenhouse gas emissions by up to 74% (Alternative Biodiesel Vehicle). Unlike petroleum-based diesel, biodiesel made from soybeans is biodegradable, nontoxic, and can be produced from renewable resources. This makes it an environmentally friendly alternative that supports sustainability. Soy-based biodiesel can be used in diesel

engines without modification and burns more cleanly, reducing pollutants such as particulate matter and carbon monoxide.

Biodiesel is produced through a chemical process called transesterification. In this process, the fatty acids in soybean oil are combined with alcohol and a catalyst (typically a strong base or acid), yielding two primary products: biodiesel and glycerin. Approximately 80% of the oil is converted into biodiesel, while the remaining 20% yields glycerin, a valuable byproduct used in soaps, cosmetics, and personal care products. This dual-purpose production adds economic value to the process and supports a variety of industries.

The biodiesel industry in the United States saw minimal activity in the 1990s. However, by the early 2000s, biodiesel production began to surge, growing from just over 8 million gallons to over 600 million gallons per year (Alternative Biodiesel Production). Technological advances, policy support, and increasing demand for renewable energy sources drove this rapid growth. Much of this growth is tied to the extensive use of soybeans not only for food and livestock feed but also for fuel production. The rising global demand for soybeans has contributed to higher market prices, further motivating investment in soybean farming and processing.

Kansas Industry Information:
In Kansas, soybeans play a significant role in both the agricultural economy and renewable energy development. The state is home to around 12,000 soybean farms and ranked 10th in soybean production nationwide in 2020. That year, the average soybean harvest in Kansas reached 50.2 bushels per acre (Kansas Frequently). While a large portion of Kansas soybeans are processed for their protein content (primarily used in livestock feed), the extracted oil is used for a variety of purposes, including human consumption and biodiesel production.

Kansas is also a significant player in the biodiesel industry. The state produces approximately 51 million gallons of biodiesel fuel annually (Kansas Biodiesel). This production not only helps reduce the nation's carbon footprint but also supports the local economy by creating jobs throughout the supply chain. Farmers grow and harvest the soybeans; truck drivers transport them to processing plants; and workers operate those plants and manage the distribution of biodiesel. Additionally, fuel stations that offer biodiesel support further employment opportunities, extending the economic benefits beyond agriculture into transportation and retail.

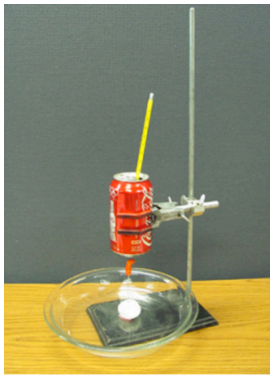
Figure 1: Ring stand setup

Materials:

- Ring stand or other type of can support, see Figure 1
- Aluminum pop can
- Pyrex pie plate or dish

- Flamin' Hot Cheetos® (soybean oil), enough bags for students to see ingredients and eat a few.
- Peanuts, wood, or dried algae as other fuel sources
- Modeling clay to hold a paperclip
- Large paperclip
- Graduated cylinder or beaker
- Celsius thermometer
- Lighter or matchstick
- Water
- Scale

Instructional Format:

1. Review background information.
2. Conduct engagement exercise.
3. Complete the activity.
4. Conduct assessment exercise.

Engagement:

Introduction: Lay the Flamin' Hot Cheetos bags on desks or tables as the students enter the class. Tell them not to eat them, YET! Then ask, 'Who wants to burn a Cheeto today?'

Procedures:

Optional: Prior to teaching this lesson, you can teach the associated Fueling Up with a Career in Biofuel by Andrea Gardner. https://www.agclassroom.org/matrix/lesson/614/

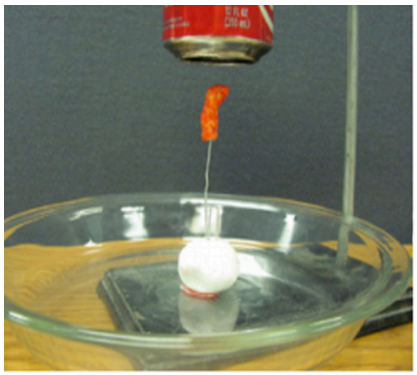

Figure 2: Paperclip and Clay

1. Briefly review the Background Information section above. Then, read the Kansas Connections section out loud.
2. Ask students why we would want to burn a Cheeto. What will we get?
3. Ask how Cheetos are made and have them examine the bags on the tables, specifically the ingredients.
4. Explain to students that they will see how much energy is in a Cheeto. Cheetos are fried in soybean oil. Could soybean oil be used as a fuel?
5. Inform students that renewable fuels are grown right here in Kansas. One is soybean oil. Explain that renewable fuels are called biofuels. Biofuels can be derived from crops such as corn and soybeans. Tell them that today, they will burn various types of biomass to explore its potential as a biofuel.
6. Use the ring stand to hold the aluminum can as pictured in Figure 1.

7. Place a handful of modeling clay on the bottom of the ring stand or in a Pyrex dish at the bottom of the ring stand.
8. Open one side of a large paper clip and place the bent portion into the clay, as shown in Figure 2.
9. Impale (spear) half a Cheeto onto the paper clip. (If you use more than half a Cheeto, you may set off a smoke detector.)
10. Weigh the dish with the clay, paperclip, and Cheeto—record in grams in space W1 of the chart.
11. Move the can to within two inches or five centimeters of the impaled Cheeto.
12. Measure and add 100 milliliters of water to the can.
13. Record the temperature of the water in ℃ and record it in space T1.
14. To find out how many calories are stored in the soybean oil in half a Cheeto, light the Cheeto and burn it to see how much energy is produced, as noted by the rise in water temperature. See the Calorie Conversion chart below.
15. Record the water temperature as soon as the flame burns out—record as T2 on the chart.
16. Weigh the plate again with the clay and paperclip, and record it as W2.
17. Calculate the calories using the formula on the *Calorie Calculation* sheet.
18. Repeat the procedure two more times. Then find the average energy used by half of a Flamin' Hot Cheeto!
19. Repeat the procedure with a peanut, a piece of wood, or another type of biomass.

Vocabulary:

- **Biomass:** renewable energy from plants and animals
- **Biofuel:** transportation fuels such as ethanol and biomass-based diesel fuel that are made from biomass materials.
- **Biodiesel:** a fuel made from vegetable oils or animal fats
- **Ethanol:** a fuel produced by the fermentation of products high in starch, such as corn
- **Fossil fuel:** a natural fuel such as coal or petroleum formed in the geological past from the remains of living organisms
- **Non-renewable resource:** a resource that cannot be readily replaced by natural means at a rate equal to its consumption
- **Renewable resource:** a resource that can be replaced naturally or by human efforts
- **Petroleum:** a naturally occurring liquid found in geological formations beneath the Earth's surface, which is often refined into fuel
- **Diesel fuel:** combustible liquid used as fuel for diesel engines such as trucks, tractors, etc.

Kansas Standards:

Next Generation Science Standards

Matter and Its Interactions

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.
Energy
MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

Language Arts

3rd Grade

Writing
Research to Build and Present Knowledge
W.3.7 Conduct short research projects that build knowledge about a topic.
W.3.8 Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.
Speaking and Listening
Comprehension and Collaboration
SL.3.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups and teacher-led) with diverse on third grade topics and texts, building on others' ideas and expressing their own clearly.
SL.3.2 Determine the main ideas and supporting details of a text read aloud or information presented in diverse media and formats, including visually, quantitatively and orally.
SL.3.3 Ask and answer questions about information from a speaker, offering appropriate elaboration and detail.
Presentation of Knowledge and Ideas
SL.3.4 Report on a topic or text, tell a story or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace.
SL.3.6 Speak in complete sentences when appropriate to task and situation in order to provide requested detail or clarification.

4th Grade

Writing
Research to Build and Present Knowledge
W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic.
W.4.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information and provide a list of sources.
Speaking and Listening
Comprehension and Collaboration
SL.4.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups and teacher-led) with diverse partners on fourth grade topics and texts, building on others' ideas and expressing their own clearly.
Presentation of Knowledge and Ideas

SL.4.4 Report on a topic or text, tell a story or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

5th Grade
Writing
Research to Build and Present Knowledge
W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic.
W.5.8 Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work and provide a list of sources.
Speaking and Listening
Comprehension and Collaboration
SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups and teacher-led) with diverse partners on fifth grade topics and texts, building on others' ideas and expressing their own clearly.
SL.5.2 Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively and orally.
Presentation of Knowledge and Ideas
SL.5.4 Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

Mathematics
6th Grade
6 EE. Apply and extend previous understandings of arithmetic to algebraic expressions
6-7 NS. Apply and extend previous understandings of operations with positive rational numbers to add, subtract, multiply, and divide all rational numbers
7th Grade
7 RP. Analyze proportional relationships and use them to solve real-world and mathematical problems.
8th Grade
8G. Solve real-world and mathematical problems involving measurement.

National Ag Literacy Standards:
Agriculture and the Environment
- Recognize the factors of an agricultural system which determine its sustainability (T1.6-8 h.)

Plants and Animals for Food, Fiber, & Energy
- Identify renewable and nonrenewable energy sources (T1.6-8 d.)

Food, Health & Lifestyle
- Identify agricultural products (foods) that provide valuable nutrients for a balanced diet (T3.6-8 g.)
- Identify sources of agricultural products that provide food, fuel, clothing, shelter, medical, and other non-food products for their community, state, and/or nation (T3.6-8 i.)

Culture, Society, Economy, & Geography
- Consider the economic value of agriculture in America. (T5.6-8 a.)

Supporting Resources:
Fueling Up for a Career in Biofuel by Andrea Gardner
https://www.agclassroom.org/matrix/lesson/614/

Grow it Now, Drive it Later? By Debra Spielmaker
https://utah.agclassroom.org/matrix/lesson/280/

Youth Education, Kansas Soybean Commission
https://kansassoybeans.org/about-the-checkoff/youth/

Soybean Byproducts Poster
https://ksagclassroom.org/supporting-resources/soybean-byproducts/

Soybean Fun Facts Poster
https://ksagclassroom.org/supporting-resources/soybean-fun/

Career Information: Agricultural Scientist
Agricultural scientists research ways to improve the efficiency, safety, and sustainability of farms and food production. Their work encompasses developing renewable fuel sources from crops such as soybeans, enhancing crop yields, and improving food quality and safety. Most positions require at least a bachelor's degree in agricultural science or a related field, though many scientists pursue advanced degrees. As of 2023, the average annual salary for agricultural scientists was approximately $74,940, with higher earnings for those in research or government roles.

Assessment: The reflection questions and trial worksheet can be used as assessments for this activity.

Author: Adapted by Amy Benz**,** retired middle school technology teacher, St. Marys, KS, from "Grow it Now, Drive it Later?" by Debra Spielmaker, and edited by Marissa Cook, Secondary Education Major at KSU, KFAC intern.

References:

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Calorie Calculation

Begin with...

- Amount of water used (___ grams)
- Temperature of water in °C before burning
- Temperature of water in °C after burning
- Difference in temperature

Calories = (mass of water in grams) x (temperature change in °C)

Example:

- 100 grams of water are heated, and the temperature increased by 10°C;

Calories = (100 grams of water) x (10°C)

Calories = 1000

- This calculation is in small calories. There are 1000 calories in a food Calorie, or large Calorie (kcal). To convert small calories to large Calories (kcal), divide the number of small calories by 1000.

Calories (food) = small calories / 1000

Name: _____ Date: _____

Flamin' Hot Cheetos

How much energy is in soybean oil?

	Initial water temperature, in Celsius	Final water temperature, in Celsius	Change in water temperature	Initial fuel weight, in grams	Final fuel weight, in grams	Change in fuel weight	Calories per gram of fuel
Trial 1							
Trial 2							
Trial 3							

Add the last three columns and divide by 3.
This is the average calories per burn.

Answer: _____

Flamin' Hot Cheetos

Soybean Oil vs. Other Biofuels

Alternative fuel source: _____

	Initial water temperature, in Celsius	Final water temperature, in Celsius	Change in water temperature	Initial fuel weight, in grams	Final fuel weight, in grams	Change in fuel weight	Calories per gram of fuel
Trial 1							
Trial 2							
Trial 3							

Add the last three columns and divide by 3.
This is the average calories per burn.

Answer: _____

Flamin' Hot Cheetos

Reflection Questions

1. Which fuel was better? Why?

_____

_____

_____

2. What were the pros and cons of each fuel?

_____

_____

_____

3. What does the use of soybeans as a fuel allow us to consider in the future? Think outside the box!

_____

_____

_____

4. Soybeans are used to create biodiesel. It is renewable, non-toxic, and biodegradable. Soybean biodiesel produces cleaner emissions. How would agriculture change if producers could grow their own fuel? How would the world change?

_____

_____

_____