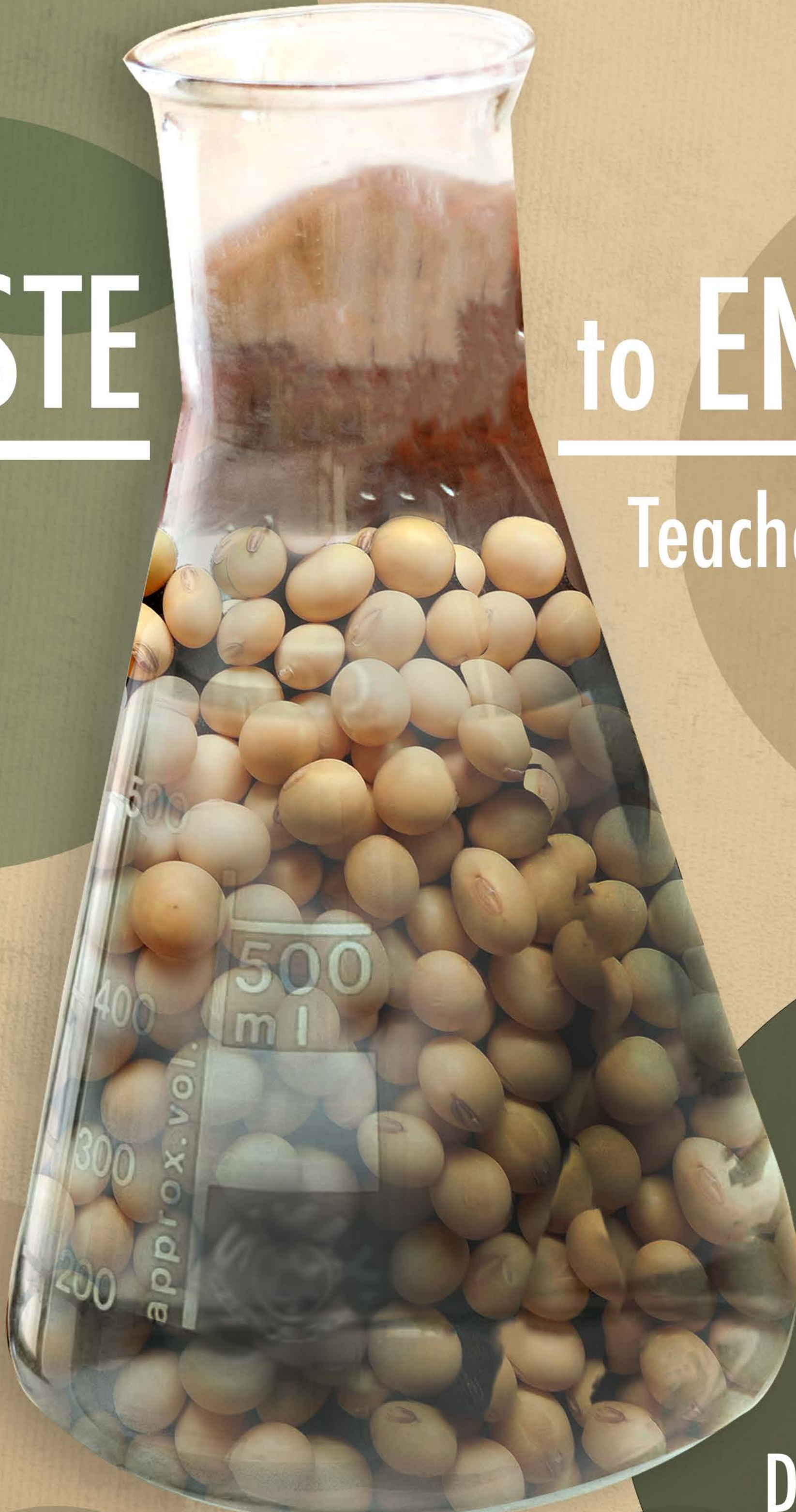
WASTE to ENERGY

Teacher Resource



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A NiSource Company

University of Findlay
Meaningful Lives. Productive Careers.

Waste to Energy Teacher Resource

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Acknowledgements

The authors wish to thank the continued and generous support of the Columbia Gas Foundation with respect to the production of this teaching resource, as well as the College of Sciences, College of Education, and the Mazza Museum at the University of Findlay. The amount of support, feedback, and encouragement that we have received from colleagues across UF is overwhelming and has made the journey so much more rewarding. We also wish to thank our student workers, including Megan Dohoner, Caleb Evans, and Breanna Gilbert, for their tireless effort in helping to construct and create the Waste to Energy content. This truly has been a team effort, and we are blessed to be surrounded by such an amazing and talented team.

Table of Contents

1 Teaching Waste to Energy

Science and Agriculture Teachers reach a large variety of students who will pursue a diverse set of vocations. Science teachers work with students of all ages, while agriculture teachers normally teach at the secondary level. Agriculture curriculum at the secondary level specifically educates students in agricultural production, agricultural business, veterinary science, as well as plant, animal and food systems. Agriculture teachers must also show students how to use any equipment or tools appropriately. They develop hands-on projects to prepare students for a possible career in this field, which closely aligns with the STEM models of science teachers. All science and agriculture teachers and curricula seek to support lesson planning and instruction that prepare and inform their students, monitor the progress of their students' learning and prepare them to be science literate citizens and members of the national workforce.

While the formal classroom of a "science teacher's" realm spans a complex continuum from Preschool to Secondary School aged youth, Agricultural Educators focus on areas that align well with national science standards and current STEM models of project based instruction. It is with this in mind that this resource was produced by science faculty, STEM educators, and teachers.

This resource guide uses STEM and new innovative methods to support teaching that focuses on different ways to deliver science content and skills in novel and engaging ways, focusing on "Waste to Energy". Soybeans are a theme and model for many engaging science and agriculture activities and educator support materials, as well as being prominent in the agricultural community. Thus, we chose to focus upon the science of soybeans and their products as it relates to energy and industry.

Useful for all teachers, this guide was designed to be a particularly supportive way to get a learner's attention in the agricultural classroom, and attempt to include often overlooked opportunities to blend science content and skills with the traditional agricultural curricula. Once a learner is engaged, the work of sharing knowledge and skills become a much easier task.

Many organizations have developed resources for science educators, and a good number of organizations support agricultural teachers. However, few resources merge the two approaches. The flow of this resource moves the learner from life sciences, to physical sciences, to earth science in a seamless process that introduces and encourages safety practices and science content across the activities.

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Here is a brief overview of this resource by Chapter:

Section	Title	Focus
Chapter 1	Teaching Waste to Energy	Introduction to the Resource
Chapter 2	Lab Safety and Chemical Hygiene	Safety First with a highlight on chemical handling and integrations into the laboratory setting.
Chapter 3	Growing Soybean and Other Biofuel Plants	Life Science to Field Science, Plant Growth Basics.
Chapter 4	Harvesting Biofuels	Applications to make students feel the connection to their lives.
Chapter 5	Waste Oil Titration	Quantitative Analysis and Applied Calculations
Chapter 6	Formation of Biodiesel	Introduction to Agriculture Production and Engineering
Chapter 7	Testing Biodiesel	Isolation and Characterization of Agricultural Products
Chapter 8	Energy and Biofuels	Differentiation Between Qualitative and Quantitative Observation
Chapter 9	Viscosity and Biodiesel	Applying Skills, Taking the time to look at variables.
Chapter 10	Soybean and STEAM Education	Approaches to integrate the arts and other engaging topics.
Chapter 11	Standards, Literacy Frameworks and Additional Resources	Connection to Standards, Literacy, and More.

As the nation continues to advance through the third decade of the 21st century, there is a growing need to prepare a citizenry and workforce in STEM fields and also take appropriate initiatives to prepare local expertise in these fields. Science educators have recognized the need to take action to motivate more middle and high school students towards the STEM pipeline and skills that support related vocations. It is a challenge for many high schools in the US to get a sufficient number of students to choose to enroll in STEM related academics, and programs like Agriculture Education can aid in this need. The authors hope that this teaching resource will further STEM engagement with students and inspire many to enter the workforce in areas involving science and agriculture.

2 Lab Safety and Chemical Hygiene

Working safely in a laboratory or out in the field is important to discuss before any activity that includes handling of chemicals or use of equipment or machinery. Always discuss the safety recommendation with students before doing any activity. Here are some basic ideas for working with the activities in this guide. Remember safety is everyone's responsibility.

Waste to Energy Lab Safety Sheet

1. Eye protection must be worn in the lab. This includes but is not limited to goggles, safety glasses, and/or face shields. Some chemicals may be harmful to your eyes, and therefore the use of contact lenses are not recommended.
2. Do not drink, eat, or smoke in the lab.
3. Be thoughtful in handling chemicals or running machinery. Label any container used to hold liquids, even if it is just water. Do not operate equipment or machinery when angry or upset.

4. No horseplay is allowed in the lab.
5. Make sure to always clean glassware and equipment before and after conducting the lab. Do not use cracked or broken glassware.
6. Learn the locations of the safety equipment and how to use them.
7. Make sure you are wearing appropriate clothing in the lab. It is recommended to wear closed-toed shoes, long pants, and to refrain from flammable knit clothing. Also, avoid wearing clothing made of synthetic fibers (e.g., nylon), as those could melt to your skin.
8. If you are working with an open flame, make sure to secure any jewelry or hair so that it does not fall into the flame.
9. Never taste any chemicals, and if you are smelling the chemicals make sure to gently woft the vapors towards your nose with your hand so you do not directly put the chemicals

under your nose (always ask your Instructor first if it's okay to woft before you try this).

10. Report all accidents, injuries, close calls, glass breakage, and spills to your Instructor immediately.
11. Treat all chemicals with respect and know the hazards before you handle the materials. If you aren't sure how to handle a chemical, ask your Instructor!
12. Read chemical labels carefully and make sure to never use any unlabeled chemicals in the lab.
13. Never return unused reagents to the reagent bottle in order to limit cross-contamination of chemicals.
14. Clean up all spills immediately.
15. Make sure to always dispose of chemicals properly and never discard chemicals in the sink unless you are instructed to by your instructor. Again, if you aren't sure how to dispose of a chemical, ask your Instructor!
16. Always turn off Bunsen burners and hot plates when you're not using them. Unplug equipment before leaving the laboratory. Remember that hot glassware and cold glassware look alike...so be careful when handling equipment that's been heated up!
17. Clean your laboratory bench and all equipment used at the end of the lab.
18. Make sure to be well rested and fueled before conducting any labs in order to better conduct all lab activities.

Check professional societal organizations for safety specifics in your field.

Safety is everyone's responsibility.

I know it is very important to practice lab safety. I have reviewed these safety rules with my teacher and I agree to follow these science lab safety rules.

Student's Signature:____

Date:_____________

For an additional example of a Safety Contract, use the following link:

https://www.flinnsci.com/api/library/download/80efae9513b548d6999c31d38ac36abe

Activity Title: Homemade Hand Sanitizer

Suggested Grade Level for Activity

K-12

Time

1 day (1 class period)

Skills Assessed

- The ability to measure liquids precisely.
- The ability to clean equipment in order to avoid cross contamination

Anticipated AgEd Outcome

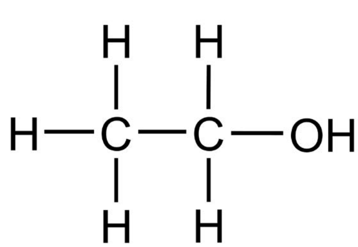
- Plants and Animals for Food, Fiber, and Energy
- Science, Technology, Engineering, and Mathematics

Introduction

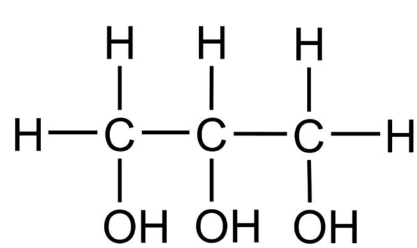
Have you ever looked at the ingredients in a bottle of hand sanitizer? If you have, there might have been one interesting ingredient: glycerol (sometimes referred to as "glycerin"). Glycerol plays a major role in the hand sanitizer formulations and other household goods. Traditionally, glycerol has been used in cosmetics and personal hygiene products. It's also found as an inactive ingredient in almost every commercial hand sanitizer (inactive, meaning it doesn't actually destroy bacteria or viruses). We know that proper hand hygiene is important in labs to prevent contamination of experiments and to ensure that we don't contaminate any of our personal belongings after we leave the lab. However, the recent COVID-19 pandemic has made hand hygiene even more critical in our daily lives.

The CDC recommends that for a hand sanitizer to be effective, the solution must remain on the user's hands for at least 20 seconds. The actual active ingredient (what actually destroys harmful pathogens) in hand sanitizer is an alcohol, like ethanol or isopropyl alcohol. The alcohol works by degrading a virus's lipid envelope (the virus's protective outer wall) or by clumping or denaturing its proteins. Due to the fact that most alco-

Ethanol



Gylcerin



hols have a very low boiling point, hand sanitizers with large percentages of alcohol evaporate quite quickly causing the hand sanitizer to come up short of the minimum 20 second requirement and thus unable to neutralize any germs on your hands. With the addition of glycerol to the hand sanitizer, the solution's evaporation rate decreases causing the hand sanitizer to stay on the user's hands longer and for at least 20 seconds.

The reason that ethanol's evaporation rate is faster than glycerin is because it is considered a simple alcohol, while glycerin is considered a sugar alcohol. This means that ethanol has one hydroxyl group (OH bond), while Glycerin has three hydroxyl groups. The more the hydroxyl groups a molecule has the more hydrogen bonds the molecule can form. As it's a strong force, the hydrogen bond takes a large amount of energy to break, or in this case evaporate the material (go from the liquid to the gas phase). The more hydrogen bonds a molecule has, the more energy that is needed to break the bonds between molecules (called intermolecular forces, see Chapter 7 for a greater discussion on this concept). Therefore, glycerin needs more energy to evaporate off your skin. This leads to glycerin having a lower evaporation rate, because it takes more time to evaporate than ethanol, which allows the combined solutions to stay on your hands longer. The glycerin has an added benefit of helping to moisturize your skin and prevent overdrying your hands.

In this lab, you are going to learn how to make your own hand sanitizer from common ingredients with glycerol and in doing so practice your lab skills including measuring out precise amounts and carefully following a lab procedure.

With the addition of glycerol to the hand sanitizer, the solution's evaporation rate decreases causing the hand sanitizer to stay on the user's hands longer and for at least 20 seconds.

Resources/Enhancements

Form more information on sanitizers and disinfectants, please see the following source: https://cen.acs.org/safety/consumer-safety/chemists-guide-disinfectants/98/web/2020/05

Pre-Lab Questions

1. What is the main ingredient in hand sanitizer?

2. Why is it important to keep your hands clean before and after performing a lab?

3. Why do some hand sanitizers dry out your hands, but others do not?

Note to Instructors: The following Procedure makes 465 mL (close to 16 oz) of hand sanitizer. These amounts can be cut in half or one third if more feasible.

Materials Needed

- 350 mL of Isopropyl alcohol (99%)
- 10 mL of Glycerol (sometimes called “Glycerin”)
- 15 mL of Hydrogen Peroxide
- 90 mL of distilled water (or boiled tap water and then cooled to room temperature)
- 1 spray bottle (at least able to hold 473 mL or 16 fl. oz) or several personal size small squeeze bottles (2 fl. oz each).
- 100 or 1000 mL graduated cylinder
- 600 or 1000 mL beaker (optional)
- 1 funnel (optional)

Cautions: Isopropyl alcohol and the hand sanitizer formed is flammable and should be kept away from heat sources and open flames. Additionally, for all reagents used, avoid contacting with your eyes. Wear protective goggles during the experiment.

DESCRIPTION

1. Use a 100 or 1000 mL graduated cylinder to measure out 350 mL of Isopropyl alcohol. Make sure to read the graduated cylinder at eye level from the bottom of the meniscus.
2. Add the alcohol to the spray bottle (or a 600 or 1000 mL beaker if using squeeze bottles). Students may choose to use a funnel for assistance in pouring the substance from the graduated cylinder into the spray bottle.
3. Clean the graduated cylinder and repeat the measuring process for 10 mL of Glycerol or Glycerin.
4. Add the Glycerol or Glycerin into the spray bottle (or beaker). This material tends to be very sticky. Thus, you can use a glass stir rod or metal scoopula to scrape the glycerol into the bottle. You can also pour some of the isopropyl alcohol in the spray bottle back into the graduated cylinder and stir to dissolve the residual glycerol. You can then transfer that mixture back into your spray bottle.
5. Once you’ve transferred all of the glycerol using the method described above, clean the graduated cylinder and repeat the measuring process for 15 mL of Hydrogen Peroxide.
6. Add the Hydrogen Peroxide into the spray bottle (or beaker).
7. Clean the graduated cylinder and repeat the measuring process for 90 mL of distilled water (or tap water that’s been boiled and then cooled to room temperature). Note: *Less water may be used in order to maintain the correct proportions of alcohol to the mixture. If a lower-concentration of alcohol is being used, keep in mind that ¾ of the mixture must be alcohol in order for the sanitizing spray to be effective.*
8. Add the distilled water (or boiled water) into the spray bottle (or beaker).
9. Put the lid on the spray bottle tightly and give the bottle a gentle stir. If utilizing 2 oz squeeze bottles, carefully stir the contents of the beaker and then use a funnel to fill each of the bottles.
10. Normally we aren’t allowed to touch our experiments, but this hand sanitizer is safe to use on your hands. However, you might want to test it out first, specifically if it passes the “20 second test.” Spray or squeeze some of your sanitizer out on a surface like your bench top in the lab and time how long it takes to completely evaporate. Does your sanitizer pass the test?

Post-Lab Questions

1. A certain ideal percentage of alcohol is needed in hand sanitizer for it to be effective. What was that amount again? What would be the issue with your sanitizer if you didn't follow the procedure correctly when measuring out the isopropyl alcohol and didn't use enough in your mixture?

2. Soap and water has also been found to be effective at removing bacteria and viruses from your hands. How does soap and water work at neutralizing germs and how does that compare to how hand sanitizer works? Do some research online and see if one works better than the other at cleaning your hands and why that might be.

3. As hand sanitizer became more heavily utilized due to COVID-19, stories about cars and trucks catching fire from personal bottles of hand sanitizer being left in hot vehicles in the summer began circulating the internet and reported by news agencies. What is the actual risk of that happening? Do you need to worry about small bottles (like the ones you made today in the lab) being left in a hot car? Watch this news report and then discuss the actual risk involved: https://www.youtube.com/watch?v=gzjIGt94_Jg

Notes

3 Growing Soybeans and Other Biofuel

Activity Title: Soybean Seed Germination

Suggested Grade Level for Activity	Time
High School	7-12 days (class periods)

Skills Assessed	Anticipated AgEd Outcome
• Comprehension of plant growth • Process of Photosynthesis	• Plants and Animals for Food, Fiber, and Energy • Science, Technology, Engineering, and Mathematics

Introduction

While some plants can reproduce asexually or by producing clones, many other plants produce seeds through sexual reproduction. For these plants, survival depends on germination of seeds and viability of young plants. If a seed germinates in the wrong place, at the wrong time, or under the wrong conditions, then life is over for that individual.

In this lab, student groups will design and conduct experiments on seed germination to explore the effects of abiotic and biotic factors on plant survival. Plants require certain factors to grow successfully. They need abiotic factors such as water, light, nutrients, a substrate to grow in, and a suitable temperature. If these are not optimal for a plant, then its ability to germinate and grow can be diminished. Plant development can also be affected by biotic factors such as the age of the seed, predation or mold growth. For this particular experiment, students will seek to understand the impact of one biotic or abiotic variable on seed germination and growth. When designing and running their experiment, care should be taken by students to control all other variables except one.

Resources/Enhancements

Adapted from GrowNextGen: https://grownextgen.org/media/pages/curriculum/maintaining-our-yield/soybean-seed-germination-experiment/24727210-1614108137/soybean-seed-germination-experiment.pdf

Soybean Seed Germination Experiments

Summary

The students will design and conduct their own experiment based on some general background information they receive. This experiment will be based on seedling germination and plant growth. Students will come up with their own variables to test and then conduct their own experiment. They will create a poster display of their research project to be presented to the class.

Students will come up with their own variables to test and then conduct their own experiment.

Targets

- Determine the basic requirements for plant growth.
- Create questions to test for a scientific experiment.
- Follow the scientific method to design and carry out an experiment.
- Analyze data to develop a conclusion to validate/deny a hypothesis.
- Correct or control variables to improve experimental quality.

Background

Some plants can reproduce asexually, or by producing clones. Many other plants produce seeds through sexual reproduction. For these plants, survival depends on germination of seeds and viability of young plants. If a seed germinates in the wrong place or at the wrong time – then life is over for that individual. In this lab, student groups will design and conduct experiments on seed germination to explore the effects of abiotic and biotic factors on plant survival. Plants require certain factors to grow successfully. They need abiotic factors such as water, light, nutrients, a substrate to grow in, and often a suitable temperature. If these are not optimal for a plant, then its ability to germinate and grow can be reduced. They can also be affected by biotic factors such as the age of the seed, predation or mold growth. When the students begin to design their experiments, they should control everything but one variable.

Watch Soybean Seeds Germination and Growth Time Lapse

https://www.youtube.com/watch?v=G85PgCh8_7c

Materials Needed

- Paper
- Experimental Design worksheet
- Soybean Seeds (Different ages, same variety)
- Cups & Potting soil or Paper towels & Plastic bags
- Water
- Ruler

May need depending on experiments:

- Colored saran wrap as light filter
- Desk lamp
- Soda, Milk, Fertilizer (Miracle Grow)
- Gravel
- Whatever else the students come up with that is easily obtained
- Poster paper (1 sheet per group)
- Graph paper
- Sticky notes

Teacher Prep for Activity

Prep will vary from day to day; the students will need their notebooks once they start to plan their procedure and question. Materials may need to be collected by the teacher or student in preparation for the lab once the students have started designing their process. The day that the experiment is set up, all of their requested materials should be set out and available to them. They also need to have soil and containers to place their seeds into, depending on their procedure. Make copies of worksheets.

Seed Germination Experiment

1. Scientific Method
   i. What are the steps of the scientific method? Discuss the scientific method with your lab partner(s) and outline the steps of the scientific method in a flowchart on a piece of paper.
2. Seed Germination
   i. Create a Driving Question Board (DQB) by writing “Seed Germination” in the center of a sheet of paper. Answer the following questions and place the answers in an appropriate location on the DQB in a flowchart configuration.
      a. What do seeds need to germinate?
      b. What are different ways that abiotic factors could affect seed germination? (Soil, water, light, temperature, etc.)
      c. What are different ways that biotic factors could affect seed germination? (seed age, predation, digestion).
3. Student lab groups create a group name and a hypothesis to test. (Remember, a hypothesis must be logical, testable, and justifiable.)
4. Pass out the Experimental Design worksheet
   i. Chose an appropriate control for your experiment (half of the seeds should be controls). Control seeds are handled just like the other seeds, except that they do not receive the treatment.
   ii. Make sure the hypothesis is something

they can test. Students can measure the number of seeds germinated and/or the growth rates of plants after the seeds germinate. This can easily be calculated by dividing height of the plant by the time they have been growing.

iii. Now have each group design a procedure to test their hypothesis. Have them write out their hypothesis, materials, procedure (including what they intend to measure), and how they will compare their data to their control on their worksheet. One copy needs to be turned in from each group to make sure that it is a testable hypothesis and their procedure is something that can be done and the materials can be obtained.

iv. After reviewing the procedure for each experiment (a sample procedure has been included below), have the group look at the adjustments that need to be made. Have the groups edit their procedure on their worksheet.

5. Each group should send someone to get the materials they need to set up their experiment.

6. The student groups should follow their own procedure to set up their experiment. Have each student keep their own notes for their experiment because they will be putting together a poster at the end of their experiment.

7. This experiment will be on going, with the students watering/monitoring their seeds and plants as often as they decide in their procedure (This could occur every day, every other day, etc.)

8. After data collection is complete (probably about 2 weeks), students will summarize their data in charts and graphs. These charts and graphs can be made on a computer or by hand on graphing paper.

   i. Remember the components of a good graph.

      a. X axis – the independent or treatment variable
      b. Y axis – the dependent variable
      c. Use the proper scale – the scale should allow you to cover most of the page
      d. Clearly label the title, axis, values, and units
      e. Bar graphs are best for qualitative response variables
      f. Line graphs are best for quantitative variables
      g. Use a legend to clarify variables

9. Have the students write a lab report based on their experiment. Handout the Lab Report Guidelines worksheet and review it with the students. Have the students complete their lab report on a computer and include data charts/graphs in the report.

10. The students will then make a poster of their experiment to put on display for the class. The poster should include their hypothesis, a brief version of their procedure, and their results, including the graphs they made. An example has been included below.

11. Place the posters on display in the classroom. Each group will get up in front of the class and give a short 2-3 minute presentation on their research poster. Afterwards, the students can do a gallery walk, providing constructive and positive comments about each poster by writing it on a sticky note and placing it on the poster.

Assessments

Student assessment will be done based on the completeness of Experimental Design, data collection, and analysis of data, their poster, and their presentation.

Extension Activities

Have the students design a new experimental design for seed growth and not germination, or continue on with their experiments to see how the treatment affects the growth of the seedlings.

Sample Write-Up

Hypothesis

Seeds germinated and grown in soda will not grow as well as those grown in water.

Materials

Seeds, Paper Towels, Water, Dr. Pepper Plastic Bottles, bags or Petri Dishes, Ruler

Procedure

1. Select 10 seeds as the variable and 10 seeds as the control.
2. Place each set of seeds on a paper towel on the bottom of a plastic bottle or petri dish. One for the control and one for the variable.
3. Dampen each paper towel with same amount of the liquids (Dr. Pepper and water).
4. Check paper towels daily (except weekends) and moisten as needed.
5. Record the length of time it takes for each seed to germinate (# of days) and a seed will be considered ungerminated after 1 week of no growth.
6. After the seeds germinate, growth will be determined by measuring the height of the plant with a ruler.
7. This will be done for the next week.
8. After the data is collected, the mean number of days it takes a seed to germinate will be recorded for both the variable and the control. This will be displayed in a bar graph, with the x-axis having two categories (water and Dr. Pepper) and the y-axis being the average number of days.
9. The median will also be determined and displayed in a table for the average days to germinate.
10. The average growth for each seedling will be determined and displayed on a similar bar graph. The median will also be determined for seedling growth.

Make a sketch or insert a picture of your soy bean growth.

Experimental Design Worksheet

Group Name: Team Biofuel Date: 8/19/2021

Partners: Caleb Evans, Gwynne Rife, Nathan Tice

Hypothesis:

Seeds Grown using soda will not germinate as well (as quickly or as many) as the seeds grown using water.

Control:

Amount of sunlight, amount of liquid (same amount of water as soda), type of seed/plant, type of paper towel.

Variable:

Some plants will be given soda instead of water

Materials:

Paper towel, plastic bottle, water, Dr. Pepper, soybean seeds, and graduated cylinder (for measuring soda/water)

Procedure:

1. Select 10 seeds as the variable and 10 seeds as the control.

2. Place each set of seeds on a paper towel on the bottom of a plastic bottle or petri dish. One for the control and one for the variable.

3. Dampen each paper towel with same amount of the liquids (Dr. Pepper and water).

4. Check paper towels daily (except weekends) and moisten as needed.

5. Record the length of time it takes for each seed to germinate (# of days) and a seed will be considered ungerminated after 1 week of no growth.

6. After the seeds germinate, growth will be determined by measuring the height of the plant with a ruler.

7. This will be done for the next week.

8. After the data is collected, the mean number of days it takes a seed to germinate will be recorded for both the variable and the control. This will be displayed in a bar graph, with the x-axis having two categories (water and Dr. Pepper) and the y-axis being the average number of days.

9. The median will also be determined and displayed in a table for the average days to germinate.

10. The average growth for each seedling will be determined and displayed on a similar bar graph. The median will also be determined for seedling growth

Data: X = No Germination After 7 Days

Seed Number	Control Germination (days)	Experimental Germination (days)
1	2	3
2	3	5
3	3	x
4	x	6
5	2	5
6	4	x
7	5	4
8	3	6
9	4	x
10	3	3
Mean	3.22	4.57
Median	3	5
Plants with no Growth	1	3

Results: Did your data support your hypothesis? Why or why not? What factors could have been possible sources of error in this experiment? What could you do to improve the design, data collection, etc. from your experiment and increase the validity of your results?

My hypothesis that plants grown using soda would be less likely to grow than those grown in water was supported by this experiment. The plants in soda were both less likely to germinate and, if they did germinate, took longer to do so. According to the data, the plants grown in water were likely to germinate in approximately 3 days and were 90% successful in germinating. Meanwhile, those grown in soda only experienced 70% success in germinating and took closer to 5 days on average to do so.

No experiment is perfect and potential sources of error could include different amounts of liquid provided to the seeds. The soda and water may evaporate at different rates causing me to need to provide more liquid to one over the other. Another source of error is that not all may have received the same sunlight. Due to spacing issues, some were more aligned with the windows than others.

In order to improve my design there are a handful of things that could have been done. First, I could have tried a "lighter" colored soda. The dark color of Dr. Pepper may have had more of an impact on growth than had I used Sprite. For additional data and information I could have repeated the experiment using egg cartons and soil to test longer term impacts of seed growth when using soda versus water. Lastly, I could use Google Sheets or Microsoft Excel to perform a t-test on my data to find if there was actually a significant difference between my control and experimental group.

Refer to Page 84 in the appendix for a blank copy of the Experimental Design Worksheet

Materials Needed

- An egg carton
    - 1 Styrofoam
    - 1 Cardboard
- Tap Water
- Soybean seeds
- Graduated cylinders (10 mL and 100 mL)
- Light source
- Top soil or any other type of dirt/potting mix
- A ruler or tape measure
- Other materials dependent on student procedures

DESCRIPTION

Set-Up

1. Fill all 12 divots in the styrofoam egg carton half of the way with dirt. Press down on the dirt to form a pocket to place the soybean seed into, then place the soybean seeds on top of the dirt (one per divot).
2. Cover up the seeds with dirt until the dirt reaches approximately ¾ of way to the top of the divot walls. Make sure that none of the seeds are visible.
3. After the seeds are all covered, water each of the 12 divots with 15 mL of water.
4. Then place the carton either by a window or under another light source, like a heat lamp.
5. Repeat steps 1-4 with the cardboard egg carton.

Lab (Basic)

1. Water every seed in both the cardboard and styrofoam cartons each day with 5 ml of water after the first day they are planted. Alternatively, water 10 mL every other day or 15 mL over a weekend if necessary.
2. Repeat this watering process for a week or until desired growth period has been reached.
3. Measure and compare the growth of each seed to one another. Take the height of each divot and compare the overall size and amount of growth (e.g., leaf size).

Alternative Labs

Follow the same set-up, but make sure to use the same material for the egg cartons (either both cardboard or both styrofoam).

1. Test the impact of light exposure by placing one carton in a well lit area and one in a dark area (e.g., direct vs. indirect sunlight or covered vs. non-covered).
2. Test the impact of soil pH by adding 1 mL of vinegar to the water used to one egg carton and just regular water for the other egg carton.

Or if you would like the students to test their own hypothesis and conduct different experiments here is the procedure.

1. Student lab groups create a group name and a hypothesis to test. (Remember, a hypothesis must be logical, testable, and justifiable.)
2. Pass out the Experimental Design worksheet
   i. Choose an appropriate control for your experiment (half of the seeds should be controls).
   ii. Make sure the hypothesis is something they can test. Students can measure the number of seeds germinated and/or the growth rates of plants after the seeds germinate. This can easily be calculated by dividing height of the plant by the time they have been growing.
   iii. Now have each group design a procedure to test their hypothesis. Have them write out their hypothesis, materials, procedure (including what they intend to measure), and how they will compare their data to their control on their worksheet. One copy needs to be turned in from each group to make sure that it is a testable hypothesis and their procedure is something that can be done and the materials can be obtained.
   iv. After reviewing the procedure for each experiment, have the group look at the adjustments that need to be made and edit their procedure on their worksheet. A sample experimental design with a data table is included below:

Controls = same type of seeds, same amount of soil
Independent variable = type of soil, miracle gro instead of water
Dependent variable = plant height (in cm)

Control = normal water and topsoil
Miracle = Used 10 ml water with miracle grow instead of water, topsoil
Potting = used potting soil and normal water

	1	2	3	4	5
Control 1	.25	1	1	1	1
Control 2	.5	1.25	2.25	2.25	2.5
Control 3	1.5	1.25	2.5	2.5	2.75
Control 4	2	3	4	4	4.25
Miracle 1	1.25	2	2	2.25	2.25
Miracle 2	2.25	1.5	2.75	2.75	3
Miracle 3	2	3	3	3.5	3.75
Miracle 4	2.5	2	3	3.25	3.25
Potting 1	1.5	2	3	3	3
Potting 2	0	2	2	2	2
Potting 3	2.5	3	4	4	4
Potting 4	0	.5	1	1.25	1.25

3. Each group should collect materials they will need to set up their experiment.

4. The student groups should follow their own procedure to set up their experiment. Have each student keep their own notes for their experiment because they will be creating a report and putting together a poster at the end of their experiment to summarize their findings.

5. This experiment will be ongoing, with the students watering/monitoring their seeds and plants as often as they decide in their procedure (This could occur every day, every other day, etc.)

6. After data collection is complete (probably about 2 weeks), students will summarize their data in charts and graphs. These charts and graphs can be made on a computer (e.g., on Word or Google sheets) or by hand on graphing paper.

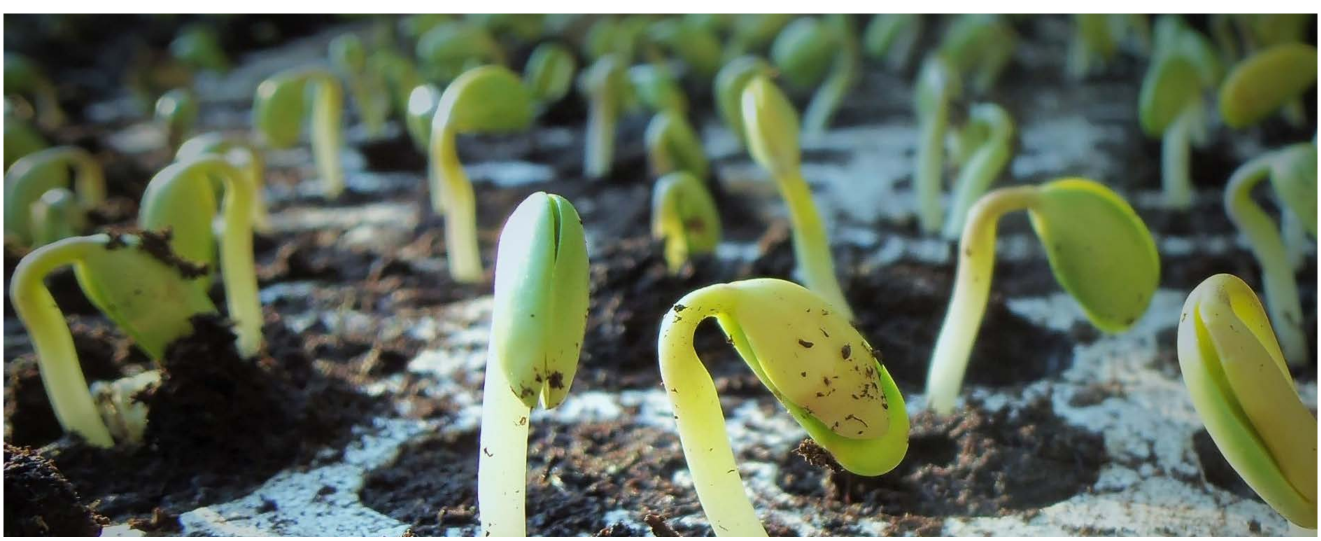
    i. Remember the components of a good graph.

    a. X axis – the independent or treatment variable
    b. Y axis – the dependent variable
    c. Use the proper scale – the scale should allow you to cover most of the page
    d. Clearly label the title, axis, values, and units
    e. Bar graphs are best for qualitative response variables
    f. Line graphs are best for quantitative variables
    g. Use a legend to clarify variables

7. Have the students write a lab report based on their experiment. Handout the Lab Report Guidelines worksheet and review it with the students and have the students complete their lab report on a computer and include data charts/graphs in the report.

8. The students will then make a poster of their experiment to put on display for the class. The poster should include their hypothesis, a brief version of their procedure, and their results, including the graphs they made.

9. Place the posters on display in the classroom. Each group will get up in front of the class and give a short 2-3 minute presentation on their research poster. Afterwards, the students can do a gallery walk, providing constructive and positive comments about each poster by writing it on a sticky note and placing it on the poster.



Student Copy

Activity Title: Soybean Seed Germination

Suggested Grade Level for Activity

High School

Time

7-12 days (class periods)

Skills Assessed

- Comprehension of plant growth
- Process of Photosynthesis

Anticipated AgEd Outcome

- Plants and Animals for Food, Fiber, and Energy
- Science, Technology, Engineering, and Mathematics

Materials Needed

- An egg carton
    - 1 Styrofoam
    - 1 Cardboard
- Tap Water
- Soybean seeds
- Graduated cylinders (10 mL and 100 mL)
- Light source
- Top soil or any other type of dirt/potting mix
- A ruler or tape measure
- Other materials dependent on student procedures

Introduction

While some plants can reproduce asexually or by producing clones, many other plants produce seeds through sexual reproduction. For these plants, survival depends on germination of seeds and viability of young plants. If a seed germinates in the wrong place, at the wrong time, or under the wrong conditions, then life is over for that individual. In this lab, student groups will design and conduct experiments on seed germination to explore the effects of abiotic and biotic factors on plant survival. Plants require certain factors to grow successfully. They need abiotic factors such as water, light, nutrients, a substrate to grow in, and a suitable temperature. If these are not optimal for a plant, then its ability to germinate and grow can be diminished. Plant development can also be affected by biotic factors such as the age of the seed, predation or mold growth. For this particular experiment, students will seek to understand the impact of one biotic or abiotic variable on seed germination and growth. When designing and running their experiment, care should be taken by students to control all other variables except one.

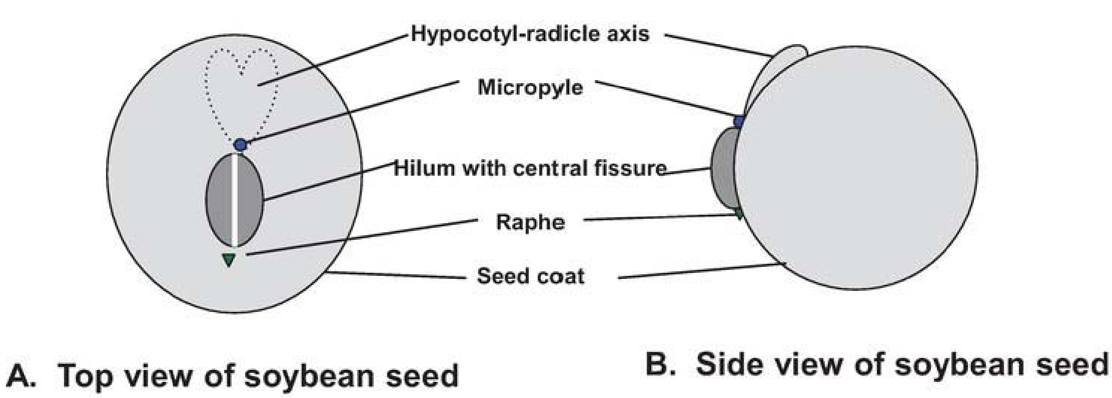
Set-Up Option 1: Testing Different Egg Cartons

1. Fill all 12 divots in the styrofoam egg carton half of the way with dirt. Press down on the dirt to form a pocket to place the soybean seed into, then place the soybean seeds on top of the dirt (one per divot).
2. Cover up the seeds with dirt until the dirt reaches approximately ¾ of way to the top of the divot walls. Make sure that none of the seeds are visible.
3. After the seeds are all covered, water each of the 12 divots with 15 mL of water.
4. Then place the carton either by a window or under another light source, like a heat lamp.
5. Repeat steps 1-4 with the cardboard egg carton.
6. Water every seed in both the cardboard and styrofoam cartons each day with 5 ml of water after the first day they are planted. Alternatively, water 10 mL every other day or 15 mL over a weekend if necessary.
7. Repeat this watering process for a week or until desired growth period has been reached.
8. Measure and compare the growth of each seed to one another. Take the height of each divot and compare the overall size and amount of growth (e.g., leaf size).

Set-Up Option 2: Student Direction Independent Variable

Follow the same set-up, but make sure to use the same material for the egg cartons (either both cardboard or both styrofoam). Students will create and design their own experiment testing a variable of their choosing. Examples Below:

- Test the impact of light exposure by placing one carton in a well lit area and one in a dark area (e.g., direct vs. indirect sunlight or covered vs. non-covered).
- Test the impact of soil pH by adding 1 mL of vinegar to the water used to one egg carton and just regular water for the other egg carton.



Pre-Lab Questions

1. What variable will you test for this lab? If choosing option 1, what is the variable provided? If choosing option 2, pick a variable that you are interested in testing.

2. How will you be sure to control all other factors that are not being tested? What variables need to be controlled and how will you keep them the same between the testing groups?

3. Why is it important to control for as many other factors as possible when performing the experiment?

4. What data will you collect during the experiment? Essentially, what will allow you to know if the variable you tested had any impact?

Post-Lab Questions

1. Did the variable you test result in any changes when it came to the soy bean plants?

2. How would you explain any difference noticed between the control and experimental group? If there was no difference, attempt to explain why no difference was seen between the two groups.

3. Soybeans, and really most plants, are not grown in egg cartons. What would the variable you tested look like in a more typical growing location (such as a large farming field)?

4 Harvesting Biofuels

Activity Title: Separating Protein

Suggested Grade Level for Activity

High School

Time

2 days (or 2 class periods)

Skills Assessed

- Ability to separate or extract the protein in soymilk

Anticipated AgEd Outcome

- Plants and Animals for Food, Fiber, and Energy
- Science, Technology, Engineering, and Mathematics

Introduction

A protein is a macromolecule (large molecule) made up of a variety of amino acids. There are 20 different standard (or alpha) amino acids that exist and they link together in large numbers to form proteins. These amino acids have different sizes and functions that can result in the protein folding in different ways, which plays a large role in how the protein functions. While many times we focus on the oil or lipids from soybeans used to make biodiesel, there is a large amount of protein contained within each bean (close to 40% of its total composition). In this lab, you will be separating out the protein from soy flakes or dried soybeans and determine your percent error based on the amount of protein you collect.

Matter and mass cannot be created or destroyed. This allows for scientists to determine exactly how much product can be created. Whatever matter is used throughout a chemical reaction or experiment can always be accounted for. If 100 grams of substance X is used in a reaction, then there will always be 100 grams of substance X. It may change form or physical state (go from a solid to a liquid) or become part of a new substance (form or break a bond due to a chemical reaction). However, the matter is always present and, depending on the experiment, can be mathematically accounted for. An experiment in which you have the exact amount of substance at the end as what you started with would have 0% error or 100% yield.

Very few scientific experiments result in 100% production efficiency. Product is almost always lost.

Very few scientific experiments result in 100% production or efficiency (called "quantitative yields"). Product is almost always "lost" due to a variety of reasons: decomposition of the product, transfer errors, or incomplete conversion to the desired product. This amount of missing product is based on the calculated amount that was possible, also known as the theoretical amount. This amount is typically not possible due to a variety of reasons (lack of efficiency, energy lost to heat, open system, etc.) but the amount that is collected is known as the yield. With both of these numbers in mind, a percent error can be found. In many lab experiments, the "percent error" is how far off you were from the potential value or, essentially, how successful you were at the lab. A percent error can be calculated by subtracting the theoretical value and the experimental value (yield), this is the error. The error is then divided by the theoretical value and multiplied by 100 to make it into a percentage. The percent error provides insight into potential sources of error. A larger source of error could provide evidence for using an incorrect concentration solution (maybe it was 2M instead of 1M) or measuring 10 grams of substance instead of 1.0 grams of substance. A smaller percent error could require a little more reflection on the lab process. It is important to note if your error resulted in too large a yield or too small a yield and attempt to make sense of it based on what took place in the lab. When completing today's lab take note of where different sources of error may come from as you work through the lab.

Resources/Enhancements

Adapted from- Purdue University's Indiana Soy Sensation
https://extension.purdue.edu/4h/Documents/Volunteer%20Resources/Past%20Congress%20Lesson%20Plans/SoysensationLessonPlanStudentGuidefinal.pdf

Pre-Lab Questions

1. What is a protein?

2. What is the law of conservation of mass and how will it apply to this lab?

3. If you collect 5 grams of protein but you could have theoretically collected 7 grams, what is your percent error?

Materials Needed

- ½ cup Soy Flakes (or dried soybeans) soaked overnight in a wide mouth jar.
- Graduated cylinder or measuring cup
    - If performing on smaller scale ½ tsp measuring spoon and pipette or eye dropper
- Vinegar
- Flask with stopper (or clean soda bottle)
    - If performing on smaller scale, test tube with stopper (or small clear tube with cap)
- 1 ½ cups tap water

DESCRIPTION

1. Soak ½ cup soy flakes overnight in a wide mouth jar of 1 ½ cup of tap water. Alternatively, dried soybeans that have been chopped via a food processor can be used and soaked the same way.

2. After the soy flakes have been soaked, insert a pipette below the top layer of oil to extract all of the protein/water solution from the jar.

3. Weigh the amount of protein/water solution collected by placing the solution in a pre-weighed flask or clean soda bottle and placing it on the scale. Add in an equal part vinegar to the solution in the flask (the amount of protein/water solution collected should equal the amount of vinegar added).

    i. If performing on a smaller scale, place 1 tsp. of the protein/water solution into a clear plastic tube. Add 1 tsp. of vinegar to the protein/water solution.

4. Cover flask with a stopper or screw on the lid to the soda bottle and invert to mix the vinegar and protein/water solution.

    i. For the smaller scale procedure, cover the test tube with a stopper and invert to mix the vinegar into the protein/water solution.

5. Let the mixture sit for about 10 minutes after mixing.

6. The soy protein solution will become insoluble in the water after the reaction with the vinegar takes place. This will leave the protein separated at the bottom of the solution.

7. Once the protein has separated, collect the protein and weigh it. Record the weight of the collected protein and compare it to the weight of the protein/water solution. Report a percent error based upon your measurements.

8. Once the protein has been weighed, dispose of the protein properly and clean all lab equipment.

Post-Lab Questions

1. How much protein was collected from your mixture?

2. What is the percent error of your protein collection based on the initial protein/water solution (your actual protein and water weights after separation compared to what the mixture was originally)?

3. What happened when you added the acid (vinegar) to the mixture?

4. What other macromolecules that occur in nature can be denatured and how would you denature them? This may require additional research.

Notes

5 Waste Oil Titration

Activity Title: Titration of Soybean Cooking Oil

Suggested Grade Level for Activity

High School

Time

1 day (class period)

Skills Assessed

- Ability to titrate solutions

Anticipated AgEd Outcome

- Plants and Animals for Food, Fiber, and Energy
- Science, Technology, Engineering, and Mathematics

Introduction

One of the issues with conversion of waste oil to biodiesel is figuring out how much base catalyst (potassium hydroxide/KOH or sodium hydroxide/NaOH) you need to use. You cannot simply weigh the amount or measure the volume of waste oil you have, as the composition of the oil is a complex mixture of different triglycerides. Thus, there is not a common formula weight and a simple way to calculate how many reactive ester bonds are present in your triglyceride mixture. So, you need to titrate with a known concentration of sodium or potassium hydroxide (you only use one type of base, with the choice usually based upon cost and availability) on a small scale to figure out the exact amount needed for larger scale biodiesel conversions. Essentially, this titration experiment is a way of calculating the amount of reactive positions available on the triglycerides present to maximize the biodiesel yield, without adding too much base and thus causing Saponification to occur (soap making). To do this, we react hydroxide base (-OH) with the ester functional groups on the triglycerides to form free carboxylic acids (a type of reaction called “hydrolysis”). Once this reaction is complete, the hydroxide has nothing else to react with and thus the pH rises in the solution. As we run this titration, we will need a visual cue to figure out when the reaction is finished (when there has been enough base added to react fully with the triglycerides). To do this, we need to use a pH Indicator that changes color when the reaction is complete but does not participate in the chemical reaction. For waste oil titrations, you can use “Phenol Red” or “Phenolphthalein’’ as the appropriate indicator (both change colors around pH of 7).

Essentially, this titration experiment is a way of calculating the amount of reactive positions available on the triglycerides.

Resources/Enhancements

Adapted from Utah Biodiesel Supply
https://utahbiodieselsupply.com/titration.php

For additional background information on titrations, please visit: https://chem.libretexts.org/Bookshelves/Ancillary_Materials/Demos_Techniques_and_Experiments/General_Lab_Techniques/Titration

Pre-Lab Questions

1. Define titration. What does it mean and why is it useful? What components are required to be able to carry out a successful titration?

2. For this particular lab, what is the chemical reaction that occurs when the solution is titrated?

Materials Needed

- 1 mL of waste vegetable oil
- 1.0g of KOH or NaOH (only one type of base is needed)
- 20 mL of isopropyl alcohol
- 1 L of Distilled Water
- Phenol Red or Phenolphthalein pH indicator
- 50 mL beakers (3)
- 50 mL graduated cylinder (if available)
- Hot/stir plate (if available)
- 1 L Volumetric or Erlenmeyer flask
- 10 ml Syringe or 50 mL titration buret

DESCRIPTION

Titration Procedure

Make sure to carefully label and keep track of your equipment and avoid cross contamination (e.g., use each beaker for one purpose). Not doing so can cause inaccurate titrations.

1. Add 1 gram of KOH or NaOH to 1 Liter of Distilled Water and stir or shake the solution around until all of the base dissolves. This will be our Titration Solution (NOTE: About every 90 days, remake this solution as it does "expire"). This will take awhile and can be done ahead of time using the aid of a stir plate and magnetic stir bar. Just one portion of the 1 L Titration solution should be more than enough for the entire class to utilize.

2. Pour about 30 mL of Titration Solution from Step 1 into one 50 mL beaker (Beaker A) and about 20 mL of Isopropyl Alcohol into another 50 mL beaker (Beaker B). This is important to do this, as accidents and spills can happen if we try to pour the needed reagents from too large of a container. The smaller solutions in beakers A and B are now easier to handle more safely.

3. Add 1 mL of waste oil to a third 50 mL beaker (Beaker C). Then, using a graduated cylinder, measure out 10 mL of Isopropyl Alcohol from Beaker B and add that into Beaker C that has the waste oil in it. If a graduated cylinder is not available, just transfer 10 mL of Isopropyl alcohol from Beaker B into Beaker C using the measurement lines on the beakers. Mix the oil & alcohol together until it's a consistent solution either by swirling the mixture or by using a stir plate and stir bar (sometimes heating the beaker will help it mix together). Add 4 drops of Phenol Red or Phenolphthalein to Beaker C.

4. Add 10 mL of Titration Solution into a syringe from Beaker A. Add Titration Solution into Beaker C drop by drop, watching for a color change each time. Hold the Beaker C in your hand and swirl the solution around for 30 seconds. If the color change goes away, add

another drop of solution from the syringe. Repeat this process until the color change stays for at least 30 seconds. Record how many mL of Titration Solution you put in Beaker C to keep the color change. Alternatively, if you have a 50 mL buret available, rinse and drain a clean buret with several portions of deionized water (5 mLs per portion) followed by several portions of the Titration solution. Then, fill the buret with at least 10 mL of the Titration solution. Perform the titration as described above using the syringe method.

5. If you're using KOH (potassium hydroxide) in the titration solution:
    i. Add 7 to the number of mLs of Titration Solution added in Step 4
6. If you're using NaOH (sodium hydroxide) in the titration solution:
    i. Add 5.5 to the number of mLs of Titration Solution added in Step 4. The result will be how many grams of catalyst you'll use per liter of oil. These "factors" that you multiply by were determined experimentally by individuals optimizing large scale fuel production.

Example Calculations

Say you have 100 liters of waste oil to be converted to biodiesel and you titrated to 4 mL of Titration Solution to get a persistent color change. If you used KOH, add 7 + 4 = 11 grams/liter X 100 liters = 1100 grams. If you used NaOH, add 5.5 + 4 = 9.5 grams/liter X 100 liters = 950 grams. Add 1100 grams of KOH or 950 grams of NaOH to the methanol to make biodiesel using this waste oil. For more examples see the appendix.

Accounting for Catalyst Purity

In most cases, it will be difficult to find 100% pure KOH or NaOH. Here's how to account for that: simply divide the "BASE" by the purity. If KOH is used and it's 90% pure, then divide 7 by 0.90 (7/.90 = 7.8). If NaOH is used and it's 95% pure, then divide 5.5 by 0.95 (5.5/.95 = 5.8). Now, instead of using 7 or 5.5, use the "corrected" numbers to calculate how much catalyst is needed. This will allow you to get an accurate calculation of the necessary amount base needed for a large scale biodiesel run that accounts for the actual amount of hydroxide in your reagent used.

With all titrations, it is recommended to do this process three times and compare each calculated value. If the results are close (+/- 1), then you are fine to proceed with the biodiesel conversion. If it is further off than that, you'll want to repeat the titrations ensuring that you follow the steps exactly until your results are close.

Post-Lab Questions

1. What was the average required amount of Titration Solution added to the waste oil and Isopropyl Alcohol solution in order to cause a color change?

2. Were the three values similar or was there a drastic difference in the recorded values?

3. If there was a drastic difference what could have caused this to occur? What sources of error could there have been in your experiment?

4. Do you think that pure vegetable oil would require more or less Titrant to complete the reaction? Why is that the case?

6 Formation of Biodiesel

Activity Title: Creation of Biodiesel from Soybean Oil

Suggested Grade Level for Activity

High School

Time

2 days (class periods)

Skills Assessed

- Ability to weigh product
- Ability to use lab equipment
- Magnetic stir/hot plate

Anticipated AgEd Outcome

- Plants and Animals for Food, Fiber, and Energy
- Science, Technology, Engineering, and Mathematics

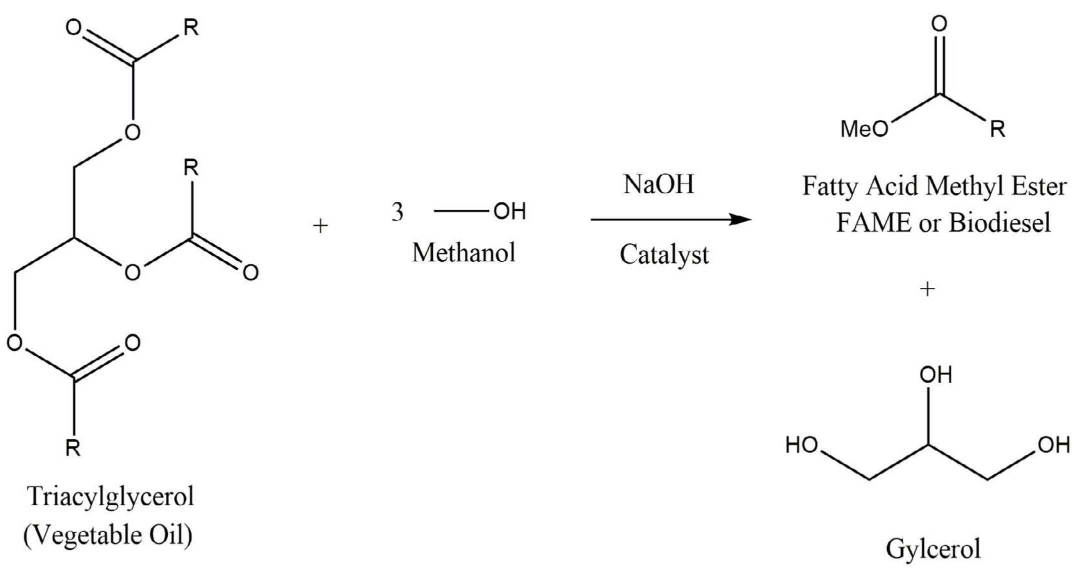
Introduction

The United States consumes approximately 60 billion gallons of diesel fuel per year through the use of diesel engines in cars, trucks, boats, and trains. Although most diesel produced in this country is derived from petroleum feedstocks, biodiesel refers to a diesel-equivalent fuel derived from biological sources such as plant oil. This “Green” fuel can be used directly in modified diesel engines, or blended with regular diesel fuel. Biodiesel usage results in the reduced emission of unburned hydrocarbons, carbon monoxide, and nitrogen oxide and is also considered to be relatively non-toxic and biodegradable. While biodiesel will not necessarily totally replace petroleum diesel, its adoption will decrease the dependency on petroleum-based fuels and improve the environmental, climate, and health effects from petroleum diesel emissions.

Most of the biodiesel produced in the US is derived from plant vegetable oils, such as soybean oil.

However, a variety of other oils can be utilized for biodiesel production, including canola, corn, peanut, and sunflower. Due to its low cost and high availability, soybean oil is most commonly used as a feedstock for biodiesel production. These natural oils contain a variety of fatty acid esters, which are converted into simpler methyl esters by a process known as transesterification with methanol in the presence of a basic catalyst such as sodium hydroxide (NaOH). Transesterification is simply a reaction that converts one type of ester (a type of "functional group") into another. The fatty acid methyl esters thus formed are the major component of biodiesel. As shown below, the only byproducts are glycerol and the sodium hydroxide catalyst ("R" on a chemical structure just represents a generic "hydrocarbon" chain, containing only carbons and hydrogens. For triglycerides, the R groups are typically 10-20 carbons long).

While most diesel produced in this country is derived from petroleum feedstocks, biodiesel refers to a diesel-equivalent fuel derived from biological sources such as plant oil.



This figure shows the conversion of Vegatable Oil to Biodiesel at the molecular level.

Resources/Enhancements

In this experiment, you will synthesize biodiesel fuel from vegetable oil by the transesterification reaction. The following procedure is for synthesizing a biodiesel from unused vegetable oil. However, this method can easily be modified for using recycled, used vegetable oil. Once done with this lab, the product needs to be stored in a safe location so it can be used in the next lab (chapter 7).

Pre-Lab Questions

1. Most oils and fats contain palmitic and stearic acid as building blocks. Draw the structures of these compounds.

2. Why practically do we need to heat up the oil for this reaction to take place?

3. What sort of potential hazards are in this lab procedure and what sort precautions should you take to ensure proper safety?

Materials Needed

- 100 mL of vegetable oil
- 20 mL of methanol
- 0.35 g of NaOH
- 250 mL beakers
- 250 mL Erlenmeyer flasks
- Separatory funnel
- Magnetic stir bar
- Hot/stir plate

DESCRIPTION

Day 1

1. Warm up to 100 mL of 100% pure vegetable oil to about 40°C in a 250 mL beaker. Although not necessary, the warming does increase the rate of the reaction.

   * If using used/recycled vegetable oil make sure to filter the oil and boil off any residual water.

2. Add 0.35 g of finely ground anhydrous NaOH into 20 mL of pure (99% of higher purity) methanol in a 250 mL Erlenmyer flask containing a magnetic stir bar. Put the flask on a magnetic stir plate, and stir vigorously until all of the sodium hydroxide is dissolved. The flask now contains sodium methoxide.

3. When all of the sodium hydroxide is dissolved, carefully pour the 100 mL of vegetable oil into the methanol/methoxide solution while continually stirring. At first the mixture will become cloudy, but should soon separate into two layers. Stir for 30 minutes on high.

4. Transfer the reaction mixture to a 250 mL separatory funnel. You should end up with two layers with the biodiesel on top. Allow the reaction mixture to sit and separate for about 1 hour. Allow the reaction mixture to sit and

Day 2

separate for about 1 hour.

5. Open the stopcock on the funnel and carefully collect the glycerol (bottom layer) in a small beaker and then set that aside. Drain the biodiesel layer into a second flask. Weigh the two products formed and record those values in your notebook.

6. Store the product in a safe location so it can be used for the chapter 7 lab. Be sure to label the container with your name, date, and name of the product.

Biodiesel can be pumped and used in farm equipment like tractors.

Post-Lab Questions

1. How much (in grams) of glycerol and biodiesel did your group collect?

2. Do you think your biodiesel is ready to be put in a diesel engine?

3. What sources of errors do you think are in this lab and how could the procedure be improved? What sorts of potential impurities could there be in this fuel that might negatively affect your car or truck?

4. What is the role of the sodium hydroxide in this reaction and why do we have to be careful to only use a small amount of it? What would happen if we used a large amount of NaOH in the reaction?

Notes

7 Testing Biodiesel

Activity Title: Biodiesel Properties Testing

Suggested Grade Level for Activity

High School

Time

1 day (class period)

Skills Assessed

- Ability to test pH
- Ability to test solubility
- Ability to calculate density

Anticipated AgEd Outcome

- Plants and Animals for Food, Fiber, and Energy
- Science, Technology, Engineering, and Mathematics

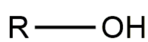
Introduction

After the formation of our biodiesel from the previous lab, we are going to run a series of tests to characterize our newly formed fuel. Commercial fuels undergo a variety of quality control procedures before they can be sold, including flashpoint testing (the lowest temperature at which the vapors of the fuel will ignite in air) and analysis for unwanted impurities (e.g., water). For this lab, we are primarily going to determine some of the physical properties of our fuel and the main byproduct of its production, glycerol. We will learn about concepts like density, solubility, and intermolecular forces. If we go back to thinking about the structures of each of our products, the glycerol is highly polar, with three hydroxyl (-OH) groups (or alcohol groups) per molecule. Biodiesel, by contrast, is quite non-polar and composed mostly of long hydrocarbon chains and one ester. Thus, these two compounds should have radically different physical properties.

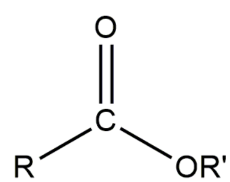
Alcohol groups are examples of what are known as “functional groups.” Functional groups are defined as specific arrangements of atoms in a molecule that lead to characteristic physical and chemical properties. Thus, all molecules that contain a particular functional group (e.g., an alcohol group) would be expected to have similar physical and chemical properties. Two other examples of functional groups include esters (which can be found in both triglycerides and biodiesel itself) and hydrocarbons (functional groups made up of only hydrogen and carbon).

The type of functional groups present on a molecule leads to different types of intermolecular forces present (London Dispersion, Dipole-Dipole, Hydrogen Bonding) and thus dictates the properties of that molecule. Thus, we can connect the particular functional groups on a molecule to things like its solubility in water. In this lab, you are going to test the biodiesel that you formed previously and investigate its properties, including its pH, miscibility, and density.

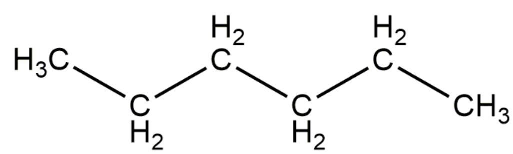
Commercial fuels undergo a variety of quality control procedures before they can be sold.



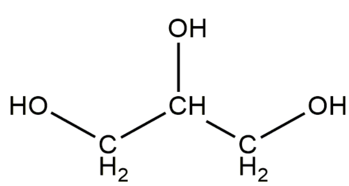
Alcohol (Hydroxyl)



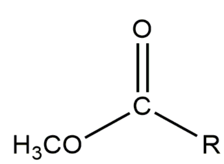
Ester



Hydrocarbon (Hexane)



Glycerol



"Biodiesel"
Fatty Acid Methyl Ester

Resources/Enhancements

The activity, Biodiesel Testing, works with highly flammable solvents such as methanol and ethanol. Please use caution and maintain standard lab safety when completeing this acitivity. Refer to Lab Safety sheet for more information.

Pre-Lab Questions

1. Which pH measurements are acidic, which are basic, and which are neutral?

2. What is the formula for density and what is the density of water? Do you think biodiesel is more or less dense than water? Why?

3. What does it mean if a substance is soluble in water? Please give an example.

Materials Needed

- 50 mL of prepared biodiesel
- 25 mL of prepared glycerol
- 2 mL of hexanes, toluene, ethanol, and methanol
- 20 test tubes
- pH test strips
- Separatory funnel 10 mL syringe
- 100 mL beaker hot/stir plate

DESCRIPTION

1. pH Testing
   i. Take your two products from your formation of biodiesel experiment and test their pH. For your bottom layer (the glycerol), pipet a drop of it into a test tube filled with 1 mL of distilled water.
   ii. Use a pH test strip to determine the pH of the solution and record your results.
   iii. Now take 1 mL of your biodiesel (top layer from the previous experiment) and place it in a test tube with 1 mL of distilled water (a bilayer should form, with the biodiesel on the top).
   iv. Carefully invert the test tube by placing your thumb over the top and place the tube upside down. Do this several times but do not shake!
   v. Place the tube right side up and use a pipet to remove the bottom layer.
   vi. Place this bottom layer in another test tube and test the pH of this layer as well with pH test strips. Record your results.
2. Miscibility
   i. Next test the solubility of each of the layers (the top biodiesel and bottom glycerol layers). For each product, test the solubility (or miscibility when referring to two liquids) in the following solvents.
   ii. Take a few drops of each product and add them into a separate test tube of 1 ml each of the solvents.
   iii. Record your results as miscible (only one layer is observed) or not miscible (two layers are observed) in the table below:
3. Density - Finally, we are going to calculate the density of the biodiesel that you make. But, first we need to clean up our crude biodiesel.
   i. First we will wash our crude product with water. Take the biodiesel that you made

Product	Water	Hexanes	Methanol	Ethanol	Toluene
Biodiesel					
Glycerol					

from the previous lab and pour it into a 250 mL separatory funnel.

ii. Add an equivalent amount of distilled water in the funnel (if you have 50 mL of biodiesel, add 50 mL of water).

iii. Cap the separatory funnel and gently invert the funnel several times.

iv. Set the funnel upright on a ring stand and allow the layers to separate.

v. Once separation has occurred, drain the bottom layer (the water layer).

vi. Repeat this "water washing" step two more times.

vii. Once your washing step is complete, drain your washed biodiesel (top layer) into a pre-weighed 100 ml beaker.

viii. We need to remove residual water by gently heating the biodiesel. Heat your beaker of biodiesel on a hot plate for about 15 minutes at 80-90 °C.

ix. After that 15 minute period, allow the beaker to cool to room temperature. Record the weight of the beaker and calculate the weight of your final biodiesel.

x. Now, carefully syringe exactly 1.00 mL of your biodiesel into a clean, dry, pre-weighted test tube or vial. Record the mass of 1.00 mL of biodiesel and calculate its density (g/mL).

xi. As comparison, do the same for the waste oil or vegetable oil that you started with and see how their densities compare. You can also compare the density of your biodiesel to that reported of pure glycerol.

Post-Lab Questions

1. What is the measured pH of biodiesel? Is it acidic or basic? What should the pH be and why did you observe the pH that you did?

2. Which solvents were the biodiesel miscible in and which solvents were the glycerol miscible in? Why do you think that is?

3. Calculate the density of the biodiesel and record your work below.

4. Look up the reported value of biodiesel and compare that to your calculated value from your experiment. Calculate the percent error of your density findings. Refer to the appendix for example calculations.

5. If the values don't match, why do you suppose that is? Was it due to experimental error? Or does it relate to the biodiesel itself that you formed?

8

Energy and Biofuels

Activity Title: Energy Content of Biodiesel

Suggested Grade Level for Activity

High School

Time

2 day (class periods)

Skills Assessed

- Observation Skills
- Data Collection
- Qualitative vs. Quantitative

Anticipated AgEd Outcome

- Plants and Animals for Food, Fiber, and Energy
- Science, Technology, Engineering, and Mathematics

Introduction

The length of time an oil burns or the amount of heat produced is dependent on energy density. Energy density is the amount of energy stored per unit volume. Although this can get more complicated in cosmology, for most systems on Earth energy density is referring to the amount of usable or accessible energy per unit volume. When it comes to energy, not all things are created equal, and energy density is a value that demonstrates that. This concept becomes extremely important when it comes to fuel and creating energy for humans to use. One common example is just how much more energy dense Uranium is than Coal. Coal has an energy density of approximately 30. This means for every gram of coal you can make 30 kJ of energy. For Uranium (used in nuclear reactions) that number is just over 80 million kJ of energy per gram!

Nuclear power plants are not always an option and vehicles will most likely not be powered by small nuclear reactors any time soon. This makes the energy content between different fuels (such as biodiesel and diesel) very important. Calorimetry allows for the study of this energy as efficiently as possible (with as minimal loss as possible). Energy can be tricky to study because energy is always being lost due to a variety of factors including dissipation (for example, some of the energy is lost as thermal energy). Calorimetry allows for a transfer of energy or heat while minimizing the amount of energy that is not successfully transferred. To do this successfully, an environment/system is created that minimizes the ways that heat can "escape" and not be measured. Then, a chemical reaction takes place and the temperature change is carefully measured as well as the mass before and after.

When it comes to energy, not all things are created equal, and energy density is a value that demonstrates that.

Once these numbers are collected, some math is required to determine how much heat was produced or absorbed. In this case, you will be heating a set amount of water using different types of fuels. Water has a specific heat of 4.18 J/(g*°C). This means it takes 4.18 J of energy to heat 1 grams of water by 1 °C. Water has a very high specific heat compared to most other substances, but everything has a specific heat value which is a constant for that substance. This leads us to the equation $q=mc\Delta t$. In this lab you will be solving for q, which stands for the amount of heat/energy transferred. The chemical reaction taking place is the burning of fuel which is being used to heat the water. By knowing the mass of the water used, its specific heat (which is a constant), and measuring the temperature change during heating, you can plug your values in to determine how much heat/energy was produced when burning the fuel. If you need more assistance, refer to the chapter 8 example problems provided in the appendix.

Qualitative data can also be used when measuring the heat content of a substance. Qualitative data are observations made that cannot be described numerically. Common qualitative results include smell, color, notable changes (such as a solid formed or a gas was created), and other observations. The quantitative part of this lab is the calorimetry lab. This lab is primarily quantitative because most of that data can be directly measured numerically or calculated. The second part of this lab is more qualitative as it relies on what the observer notices as they burn their homemade candles.

Resources/Enhancements

The activity, Energy Content of Biodiesel, works with an open flame and highly flammable materials. Please use caution and maintain standard lab safety when completeing this acitivity. Refer to Lab Safety sheet for more information.

Pre-Lab Questions

1. What will allow you to measure if a substance has a greater energy content than another substance?

2. Why will different oils burn for a different amount of time?

3. Why do you think it is important to make sure as much heat as possible is transferred to the water being heated?

4. What are some factors you feel should be kept consistent between the trials to ensure as accurate results as possible?

5. What is the difference between qualitative and quantitative?

Part 1

Materials Needed

- Biodiesel
- Diesel
- Isopropyl alcohol
- Water
- Graduated Cylinder
- Scale
- Alcohol Burner
- Lighter
- Clean, empty aluminum soft drink can
- Glass stirring rod
- Ring Stand
- Metal Ring
- Thermometer

DESCRIPTION

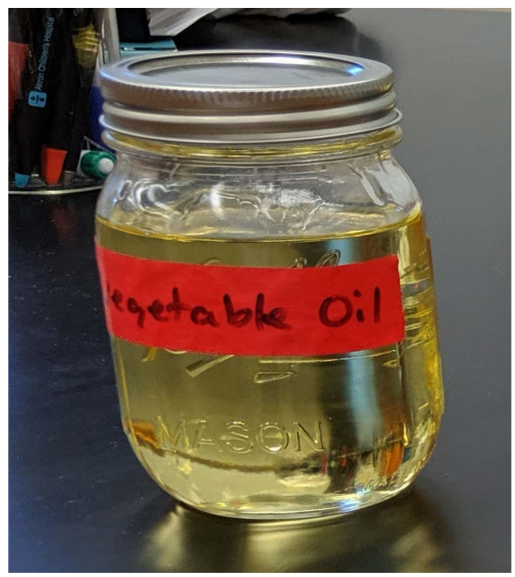
1. Set up the apparatus that will allow you to heat water and measure the temperature change.
    i. Put ring on ring stan
    ii. Pull up the tab of the soft drink can so that it is perpendicular to the top of the can (sticking straight up).
    iii. Hold the can below the ring stand so the can is below the ring but the tab is poking through the ring.
    iv. Put the glass stirring rod through the tab so the soft drink can is hanging from the glass stirring rod which is laying across the ring.
2. Fill the alcohol burner with the isopropyl alcohol and place below the can that is hanging from the ring. The alcohol will function as your control.
3. Find the mass of the alcohol burner, wick, and alcohol all combined.
4. Adjust the height of the ring so that the bottom of the can is 2 centimeters above the top of the wick from the alcohol burner.
5. Measure out and mass 100 grams of water, be sure to record the mass.

6. Pour the water into the soft drink can and record the initial temperature of the water.
7. Light the wick and heat the water sample for 5 minutes.
8. Measure the temperature during the heating process recording the highest temperature reached.
9. After the 5 minutes, extinguish the flame.
10. Mass the alcohol burner with the alcohol again once cooled.
11. Pour the water out of the can and give the soft drink can a minute to cool.
12. Repeat steps 1-11 with diesel in the alcohol burner instead of alcohol and then again with biodiesel in the alcohol burner.
    i. Be sure when repeating steps 1-11 to collect the following data:
        a. Mass of water added to soft drink can
        b. Temperature of water before and after heating
        c. Mass of alcohol burner with fuel (alcohol, diesel, or biodiesel) before and after heating.
13. Once done, clean and return all equipment to the proper location.

Part 2

Materials Needed

- Biodiesel
- WVO (waste vegetable oil)
- 2 dram vials
- Two 8 cm lengths of cotton string
- Two 6x6 cm squares of aluminum foil
- 2 mL pipet
- Fume hood (or outdoor area)



DESCRIPTION

1. Add 1 mL of biodiesel to one vial. Add 1 mL of WVO to the other vial.
2. Submerge one string into the biodiesel and one into the WVO using tweezers, making sure that the entire string has been covered with the substances.
3. Punch a small hole in the center of each aluminum foil square. Pull the string through the foil, and wrap the foil around the top of the vials. Making sure that less than 5 mm of the string is extended above the top of the vial and foil.
4. In the fume hood (or outdoor area) light the strings of each vial.
5. Compare and record the flame colors, the strength of the heat produced, and other observations.

Data Collection

Part 1

Fuel	Mass of Water	Initial Temperature	Final Temperature	Initial Mass	Final Mass
Alcohol					
Diesel					
Biodiesel					

Part 2

Fuel	Color	Strength of Heat
WVO		
Biodiesel		

Make notes and observations here.

Post-Lab Questions

1. Using the equation from the introduction and water's specific heat (4.18 J/(g*°C)) calculate the amount of thermal energy produced by the alcohol, diesel, and biodiesel.

2. Using your answers from question 1 (which will be in joules) calculate the heat of combustion for each grab of substance burned. Do this for the alcohol, the diesel, and the biodiesel. To calculate this, divide the answer from number 1 from the grams burned in the process (the difference between the final and initial mass of the fuel).

3. Using your answers from number 2, rate the three fuels from greatest to lowest energy content or energy density.

4. Based on your results and some research, which fuel would you choose to use practically? Discuss some advantages and advantages of each one (think cost of production, ease of use, heat content, etc.)

Notes

9 Viscosity and Biodiesel

Activity Title: Determination of Viscosity of Liquids

Suggested Grade Level for Activity

High School

Time

1 day (class periods)

Skills Assessed

- Data Collection
- Accuracy and Precision

Anticipated AgEd Outcome

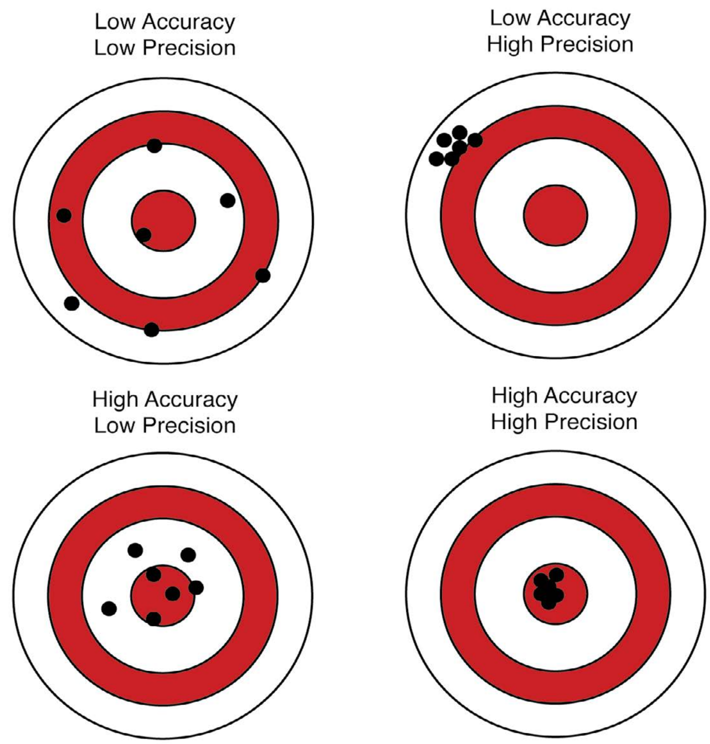
- Plants and Animals for Food, Fiber, and Energy
- Science, Technology, Engineering, and Mathematics

Introduction

This lab will measure the viscosity of water, biodiesel, waste vegetable oil (WVO), and motor oil. Viscosity is typically defined as a liquid's resistance to flow which is sometimes more commonly known as its "thickness." The more resistance to flow a liquid is the higher its viscosity. For example, honey is extremely resistant to flow and does not flow nearly as easily as water. Because of this, honey has a high viscosity compared to water while something like vegetable oil falls between the two values. Viscosity plays a variety of roles in everyday life. There are scientific reasons viscosity is important, such as the texture we experience when eating food. However, there are also economic reasons viscosity is important as the "thicker" a substance the greater its perceived value (this is more common with soaps and shampoos). However, viscosity is extremely important when it comes to oil. The viscosity of liquids changes with temperature and that includes oil which, due to weather and car function, can experience a wide range of temperatures. When you buy oil for a car it often has two numbers included (such as 5W-30). The first number, the 5W, refers to the oil's low temperature viscosity. Having a thinner oil in lower temperatures can reduce the friction and help the engine start quicker on those colder days. The number after the W, in this case 30, represents the viscosity at high temperatures (in particular, this is measured at 100°C). During the summer, the engine will benefit from a higher viscosity oil which will minimize the amount of thinning that takes place due to the increased temperature.

Researchers are constantly analyzing different oils and their properties for commercial use. In doing so, it is important they are both accurate and precise. Accuracy is how close your experimental value is to the correct answer (similar to solving for percent error in unit 4). Precision, meanwhile, is how close your data set is to each other. If you perform 3 trials and all three trials are extremely consistent (let's say you get 54 seconds, 54 seconds, and 55 seconds) then you are very precise. However, if the correct value was 30 seconds you were not very accurate. However, if you received the same three values and the correct value was 55 seconds then you were both very precise and very accurate. For scientists, precision can sometimes be the most important as you may be working with a substance with no known correct answer. Continuously receiving similar data is often the sign of potentially coming to a conclusion (or making the same mistake over and over again). Meanwhile, you can technically be accurate and imprecise. If our correct answer is 30 seconds and your data points are 15 seconds, 45 seconds, and 30 seconds your average is very accurate (perfect actually). However, your data is very imprecise. In this case, there are probably sources of errors that would need to be explained that would potentially explain why some of these values were obtained.

For this experiment, the viscosity of four liquids are going to be tested in two different ways. The first method is known as "The Ball Method." A ball is dropped into a cylinder of a given liquid, with the time taken for the ball to reach the bottom re-



corded. The longer the ball takes to reach the bottom, the more the liquid resists flow and thus has a higher viscosity. The second method is known as the "Drip Method." In this experiment, a drop of each liquid is placed on a board at an angle and the time it takes the liquid to reach the end of the board is measured. Again, the longer the time it takes the drop to reach the end, the higher its resistance to flow and the higher its viscosity.

Resources/Enhancements

The activity, Determination of Viscosity, includes dropping a metal ball in a cylinder.
Please make sure to use a plastic graduated cylinder in the Ball Method because use of a glass cylinder may lead to broken glass.

Pre-Lab Questions

1. What is viscosity?

2. Would you predict your waste vegetable oil and biodiesel to be more or less viscous than water and motor oil? Why?

3. What role does viscosity play when it comes to oil?

4. Provide an example of when someone is precise but inaccurate. Provide an explanation for why they would come up with their inaccurate answer.

Materials Needed

- Biodiesel
- Waste vegetable oil (WVO)
- Water
- Motor Oil
- 3 plastic graduated cylinders (100 mL) pipet
- A board, small metal ball, or marble (depending on what procedure is being followed).
- Stopwatch
  - "Coach My Video Edu" app for iPhone is free and can be used instead of timer. Allows for the activity to be filmed and then looked at in the app. Time can be moved forward frame by frame allowing for more accurate time measurement to the third decimal place.

DESCRIPTION - Ball Method

1. In a 100 mL graduated cylinder add 100 mL of water.
2. Obtain a small metal ball (or marble) and drop the ball into the graduated cylinder filled with water while recording the time it takes to reach the bottom with a stopwatch (or the app). This will function as your control.
3. Repeat step 2 at least 3 times noting the time each trial.
4. In 3 separate plastic 100 mL graduated cylinders add 100 mL of Biodiesel in graduated cylinder 1 and add 100 mL of WVO into graduated cylinder 2 and 100 mL of motor oil in graduated cylinder 3.
5. Take the same metal ball, making sure it has been cleaned, and drop the ball into the beaker filled with biodiesel while recording the time it takes to reach the bottom with a stopwatch.
6. Repeat step 5 a minimum of 3 times taking note of the time during each trial.
7. Take the same small metal ball, making sure it has been cleaned, and drop the ball into the beaker filled with WVO. Record the time the ball took to travel to the bottom of the graduated cylinder.
8. Repeat step 7 a minimum of 3 times taking note of the time during each trial.

DESCRIPTION - Drip Method

1. On a piece of cardboard make two marks roughly 35-40 cm apart, with one dash on top of the other dash.
   i. One dash will be near the top of the piece of cardboard while the other dash will be 35-40 cm below the original dash.
   ii. The top dash will function as a starting line and the bottom one will be the finish.
   iii. Repeat this step for 3 other locations on the cardboard (four starting lines and four finish lines in total). They can be close together, there only needs to be room for a

drop of liquid.

2. With a stopwatch in hand, get ready to record the time it takes for a drop of water to drip from the starting dash to the finishing dash on the cardboard. Hold the cardboard at approximately a 60 degree angle and adjust if necessary (drops moving too quick to measure or too slow to make it to the bottom dash).
3. With a pipet, release one drop of water on the starting dash and record the time it takes to reach the ending dash.
4. Next with a different pipet and using a different starting line, release one drop of Biodiesel on the starting dash and record the time it takes to reach the ending dash.
5. Now with a different pipet and using the next starting line, release one drop of WVO on the starting dash and record the time it takes to reach the ending dash.
6. Finally, with a different pipet and using the last starting line, release one drop of motor oil on the starting dash and record the time it takes to reach the ending dash.
7. Repeat steps 3, 4, 5, and 6 two more times and then compare the times of the control (water) with the times from the biodiesel with the times from the WVO and with the times from the motor oil.

Titration Procedure

Make sure to carefully label and keep track of your equipment and avoid cross contamination (e.g., use each beaker for one purpose). Not doing so can cause inaccurate titrations.

Data Collection

Ball Method

Liquid	Trial 1	Trial 2	Trial 3	Average
Water				
WVO				
Biodiesel				
Motor Oil				

Drip Method

Liquid	Trial 1	Trial 2	Trial 3	Average
Water				
WVO				
Biodiesel				
Motor Oil				

Post-Lab Questions

1. Based on the data collected, rate the water, biodiesel, WVO, and motor oil in order from most to least viscous.

2. Based on your trials, would you say your data is precise? Perform some research and determine the actual viscosity values of water, biodiesel, WVO, and motor oil. Are your results accurate (i.e., did your viscosity rankings align with the actual viscosities of the liquids)?

3. When it comes to use as a fuel, what would you conclude about biodiesel based on the results from the lab? Why do you come to that conclusion?

4. After performing some research, what role might temperature play in the viscosity of biodiesel and its use in vehicles? (hypothesize, perform research, and/or do the extension to answer this question)

10 Soybean and STEAM Education

Activity Title: Printing and Painting with Soy-based Ink

Suggested Grade Level for Activity	Time
K-12	2 day (class period)

Skills Assessed	Anticipated AgEd Outcome
• Creativity • Critical Thinking	• Plants and Animals for Food, Fiber, and Energy • Science, Technology, Engineering, and Mathematics

Introduction

Recently the acronym STEM has been extended to include other non-technical content areas with the addition of the A (arts) and referred to as STEAM. This provides opportunities to engage students who may not otherwise be interested in a more science directed approach. Working with agricultural models and environmentally sound practices by taking waste products and converting it to energy sources might be a hook to get students to increase their understanding in ways that interest them. Creating a works of art or composing a poem are examples of ways to include students who are drawn more to doodling than experimentation.

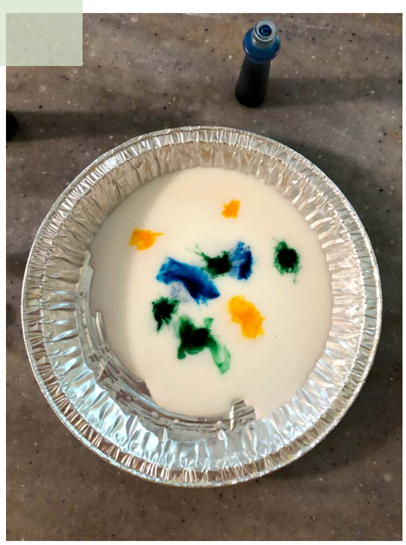
Today, about one-third of America's nearly 10,000 newspaper printers use soy based ink and more than 90% of the nation's daily newspapers are printed with color soy ink. Soy inks also work well for label printing, as they allow a reduction in ink coverage by 85% compared to water-based

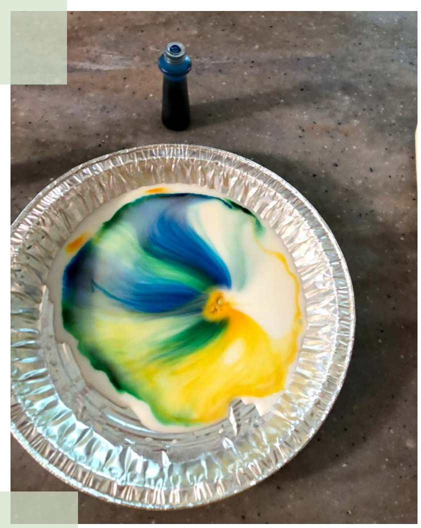
inks. Soy based ink is considered more environmentally friendly than those used in the past. For example, newspaper ink used in the past was highly toxic due to ingredients such as lead, cadmium, and other heavy metals.

Resources/Enhancements

The American Soybean Association offers background on the use of soy based inks:
https://soygrowers.com/soy-ink-seal/#:~:text=Soy%20ink%20is%20made%20from,it%20easier%20to%20recycle%20paper.s

This activity has students print or paint with soy based ink that they create.





Pre-Lab Questions

1. Would soy ink be better for printing or painting?

2. What happens when you add kool aid to milk or oil?

3. Where might you find a use for soy based ink ?

Ink is a pigment mixed in a liquid that will not blur when put on paper. Inks made with soybean oil are made from a renewable resource, are much more biodegradable and print with brighter colors that don't rub off.

Materials Needed

- Kool-Aid Packets
- Disposable Pipettes
- Water
- Balances
- Soybean Oil
- Stamps
- Small Paper Cups
- Soy Lecithin Paper
- Paper Towels
- Stir Sticks
- Soy Milk
- Watercolor Paper
- Pie Tin
- Dish soap

DESCRIPTION

1. In a paper cup, add 6g of Kool-Aid and 5mL of water and mix with a stir stick completely.
2. Next add 1mL of soybean oil to the Kool Aid solution and mix well.
3. Using a balance, weigh out 0.3g of soy lecithin granules, or 0.5mL of liquid lecithin and stir until all granules have dissolved completely.
4. Then fold a paper towel in half, then fold in half again to make a little pad.
5. Then pour the soy ink into the middle of the paper towel pad. The soy ink will soak up quickly.
6. Moisten a rubber stamp by pressing the stamp on to the soy ink in the paper towel, then print the image on paper.
7. Now take some of your ink and drop several drops on a shallow pie tin of soy milk. You can use several different colors if you have mixed up a variety of colors.
8. Add a drop of dish detergent to the dye and milk.
9. Observe the results, and when ready take a piece of watercolor paper and lay it on top and take it up to see the abstract soy painting created.

Post-Lab Questions

1. Was printing or painting easier with the soy based ink you made?

2. What happened when you added soap to the milk and soy solution?

3. What did adding the kool-aid to the milk do?

4. What happened when you added oil to the liquid? How did it change the mixture?

5. Hypothesize how you could change the ink recipe. If material is available, propose your hypothesis to your teacher and record what happens. If not available, write what you would change and what you would expect to see.

Notes

11 Standards, Literacy Frameworks and Additional Resources

The collected chapters in this resource represent a flow of activities and lessons that can support a STEM curriculum in different educational settings.

The Standards and Key Knowledge used to design this resource are summarized here with link to the most recent online locations:

Ohio K - 12 Science Standards	http://education.ohio.gov/Topics/Learning-in-Ohio/Science/Ohios-Learning-Standards-and-MC
Next Generation Science Standards (NGSS)	https://www.nextgenscience.org/#:~:text=The%20Next%20Generation%20Science%20Standards%20(NGSS)%20are%20K%E2%80%9312,science%20education%20for%20all%20students.
Ohio Agriculture Teaching Standards	http://education.ohio.gov/Topics/Career-Tech/Agricultur-al-and-Environmental-Systems
Pillars of Agricultural Literacy	https://www.agfoundation.org/pillars
Energy Literacy	https://www.energy.gov/eere/education/energy-literacy-es-sential-principles-energy-education#:~:text=Energy%20Literacy%20is%20an%20understanding,in%20terms%20of%20energy%20systems
Project PORE	https://www.projectpore.org/
Ohio Soybean Association	https://www.soyohio.org/association/

Closing thoughts on Engaging Students through Waste to Energy Activities:

Some suggest if low enrollment in STEM fields and low interest in STEM academics continue, all high school academics that link to STEM majors will be at great risk. It is often the case that too many American students conclude early in their education that STEM subjects are boring, too difficult or unwelcoming, leaving them ill-prepared to meet the challenges that will face their generation, their country and the world.

In addition to STEM innovations, another philosophical structure is gaining foothold due to the development of what is now referred to as 21st century skills, a movement toward the “4C’s” of teaching has occurred. The 4 C’s being communication, collaboration, critical thinking, and creativity. The “21st Century Skills” movement is more than a decade old. Yet, educators still pose important questions about how to move 21st century education forward. Ten years ago, National Education Association (NEA) helped establish the Partnership for 21st Century Skills (P21) and in 2002 began a two-year journey to develop what became known as a “Framework for 21st Century learning,” highlighting 18 different skills. In the last eight years, 16 states joined P21 and agreed to build 21st century outcomes into their standards, professional development, and assessments.

Over the years, it became clear that the framework was too long and complicated. To resolve this issue, there were comprehensive interviews with leaders of all kinds to determine which of the 21st century skills were the most important for K-12 education. There was near unanimity that the four specific skills previously mentioned were the most important. They became known as the “Four Cs”. Now the challenge is building the “Four Cs” into K-12 education. Discussions on this topic are pending at the federal and state levels and in many school districts around the country. To encourage more members and leaders to incorporate this policy into their own instruction, NEA developed a guide to introduce educators to the concept, stressing the importance of the “Four Cs,” and put 21st century education into classroom practice. Although different in organization, the same important components of teaching anyone science in a way that will enhance a learners understanding are present. Currently, each of the STEM disciplines have lesson structures and components that can aid teachers in reaching their learners. Traditional Science Teaching suggests that a 5E approach to lesson designs reaches and teaches science learners in the most effective way. In many ways, education focused on the sciences relates to many critical thinking skills.

Currently, each of the STEM disciplines have lesson structures and components that can aid teachers in reaching their learners.

STEM

Science • Technology
Engineering • Mathematics

Waste to Energy Teacher Resource

Here is a brief summary of a 5-E Instructional Design Philosophy that is considered best practice and commonly used for Science Classrooms:

ENGAGE

- First phase of the learning cycle.
- Teacher works to gain an understanding of the students' prior knowledge and identify any knowledge gaps.
- Foster an interest in the upcoming concepts so students will be ready to learn.
- The concept is introduced to students for the first time.

EXPLORE

- Students actively explore the new concept through concrete learning experiences.
- Provides students an opportunity to learn in a hands-on way.

EXPLAIN

• Teacher-led phase that helps students synthesize new knowledge and ask questions.

• Teachers ask students to share what they learned during the Explore phase before introducing technical information in a more direct manner.

• Teachers utilize video, computer software, or other aides to boost understanding.

ELABORATE

• Focuses on giving students space to apply what they've learned. helps them to develop a deeper understanding.

• Students create presentations or conduct additional investigations to reinforce new skills.

• Students to cement their knowledge before evaluation.

EVALUATE

• Both formal and informal assessment.

• Teachers can observe their students and see whether they have a complete grasp of the core concepts.

• Include self-assessment, peer-assessment, writing assignments, and exams.

Technology as an educational tool is generally considered a tool to integrate knowledge, and also focus on communication skills in a highly digital world. For STEM models, technology also represents the ways in which research and development moves forward relating to engineering designs. Technology often supports the skills of communication.

Engineering models for teaching focuses on the Design Process as indicated below. Collaboration is needed to successfully pursue a sound design process:

The Engineering Design Process

ASK

- What is your design supposed to do?
- How will you know if it is doing what you want?
- What could keep you from making it do that?
- How will you test your design?

IMAGINE

- Apply knowledge and creativity to brainstorm ideas together.
- Agree on one to try!

PLAN

- Consider your materials and resources.
- Sketch/draw the details.
- Pitch your plan.

CREATE

- Follow the plan.
- Test it out and compare your results to what you wanted or expected.

IMPROVE

- Analyze your test results.
- What change would make the biggest impact on meeting your goal?

Mathematical concepts and applications also offer a myriad of functional processes needed to solve and analyze questions. When a STEAM approach is added, creativity is included and learners are encouraged to develop unusual ways of solving a technical problem. Taken together, all of these approaches can be supported in a project-based approach to educating.

An agricultural educational program is an ideal place to use real world settings to apply learning through a project-based approach. No field specific instructional design is currently more accepted than other notes here, but a grassroots approach called "Farm to School" used the best philosophies from the Next Generation Science Standards, State Standards for Agriculture Curriculum, and Project-Based Approach to engage students.

Thematic approaches, like the one followed in this reference, can provide the basis for STEM learning that will encourage and support students in learning and feeling that these disciplines and vocations are within reach and can be a rewarding and effective way to move forward toward a career or vocation pathway.

The following matrix connects the activities in the Chapters with the State of Ohio Standards for Science and Agriculture and Environmental Science at the time of publication.

Chapter	Agriculture/ Environmental Science strands	Ohio New Learning Science Standards	Topics/Activity
1 Teaching Waste to Energy	Strand 1. Business Operations/21st Century Skills Outcome 1.1. Employability Skills	**Science is a Human Endeavor:** Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	STEM/Teaching
2 Lab Safety and Chemical Hygiene	Strand 3. Biotechnology Outcome 3.5. Laboratory Standard Operational Procedures	**Scientific Inquiry, Practice and Applications:** All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	Safety

3 Growing Soybean and other Biofuel Plants	Strand 3. Biotechnology Outcome 3.8. Research and Experiments Strand 8. Plant Science Outcome 8.4. Growth and Management	**Science is a Way of Knowing:** Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past, and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge	Plant Growth Basics/ Scientific Method
4 Harvesting Biofuels	Strand 3. Biotechnology Outcome 3.2. Foundations of Chemistry Strand 8. Plant Science Outcome 8.5. Harvesting	**RECALLING ACCURATE SCIENCE (R) PHYSICAL SCIENCE (PS) Topic:** Conservation of Mass and Energy This topic focuses on the e **7.PS.4:** Energy can be transferred through a variety of ways	Harvesting Biofuels
5 Waste Oil Titration	Strand 6. Environmental Science Outcome 6.9. Hazardous Materials and Waste Management	**PS.M.5: Reactions of Matter** • Chemical reactions	Titration
6 Titration of Biodiesel	Strand 6. Environmental Science Outcome 6.9. Hazardous Materials and Waste Management	**IM: INTERACTIONS OF MATTER** **C.IM.1:** Chemical reactions • Types of reactions • Kinetics • Energy • Equilibrium • Acids/bases	Biodiesel Formation

7 Testing Biodiesel	Strand 6. Environmental Science Outcome 6.8. Contaminants and Pollution Control	**Scientific Knowledge is Open to Revision in Light of New Evidence:** Science is not static. Science is constantly changing as we acquire more knowledge. **INTERPRETING AND COMMUNICATING SCIENCE CONCEPTS (C)**	Testing Biodiesel
8 Energy and Biofuels	Strand 9. Energy Outcome 9.1. Energy Sources Outcome 9.2. Crude Oil and Natural Gas	**EARTH'S RESOURCES ENV.ER.1:** Energy resources • Renewable and nonrenewable energy sources and efficiency • Alternate energy sources	Energy and Biofuels
9 Viscosity and Biodiesel	Strand 6. Environmental Science Outcome 6.7. Solid Waste and Renewable Resource Management	**C.IM: INTERACTIONS OF MATTER C.IM.1:** Chemical reactions • Types of reactions • Kinetics • Energy • Equilibrium • Acids/ bases	Viscosity
10 Soybean and STEAM education		**DESIGNING TECHNOLOGICAL/ ENGINEERING SOLUTIONS USING SCIENCE CONCEPTS (T)** **PG.ER: EARTH'S RESOURCES** **PG.ER.1:** Energy resources • Renewable and nonrenewable energy sources and efficiency • Alternate energy sources and efficiency	STEAM

APPENDIX

Potential Conversions and Calculations Examples by Chapter

All conversions used throughout the resource (in order of appearance)

1000 mL = 1 Liter
29.57 mL = 1 fluid ounce
2.54 cm = 1 inch
Percent Error = $\frac{Theoretical - Yield}{Theoretical}$ x 100
1 teaspoon = 4.93 mL
3 teaspoon = 1 tablespoon = 14.79 mL
16 tablespoons = 1 cup = 240 mL
Fahrenheit to Celsius (____°F – 32) x = ____°C
Density = $\frac{Mass}{Volume}$
Q = MCΔT
Specific heat of water = C = 4.18 J/(g*°C)
1000 grams = 1 kg
1000 J = 1 kJ

CHAPTER 2

1 fluid ounce = 29.57 mL

1. A spray bottle may hold 16 fluid ounces. How many mL of liquid will need to be created for this lab?

$$x = \frac{16\ fluid\ ounces}{1\ spray\ bottle} \times \frac{29.57\ mL}{1\ fluid\ ounce} = \frac{473\ mL}{1\ spray\ bottle}$$

2. If using personal sized containers, often 2 fluid ounces, how many mL will each person receive of the hand sanitizer?

$$x = \frac{2\ fluid\ ounces}{1\ container} \times \frac{29.57\ mL}{1\ fluid\ ounce} = \frac{59\ mL}{1\ container}$$

CHAPTER 3

2.54 centimeters = 1 inch

1. You may instinctively make your measurement in inches. In science, inches is not used because scientists use the metric system. Because of this, we will need to convert any measurements in inches to centimeters.
    a. 1 inch

$x = 1\ inch\ \text{x}\ \frac{2.54\ cm}{1\ inch}$ = 2.54 centimeters

    b. 0.8 inches

$x = 0.8\ inches\ \text{x}\ \frac{2.54\ cm}{1\ inch}$ = 2.03 centimeters

    c. 1 5/16$^{\text{ths}}$ of an inch

$x = 1\frac{5}{16}\ inches\ \text{x}\ \frac{2.54\ cm}{1\ inch}$ = 3.33 centimeters

CHAPTER 4

Calculating for error and percent error
1 teaspoon = 4.93 mL
3 teaspoon = 1 tablespoon = 14.79 mL
16 tablespoons = 1 cup = 240 mL

1. You have the potential to collect 20 grams of protein and end up collecting 17.5 grams. What is your error? What is your percent error?

Error = Difference between theoretical and yield. 20-17.5 = 2.5

Percent Error = $\frac{20-17.5}{20}$ x 100 = 12.5%

2. Your calculations state you could potentially yield 150 grams of substance X. Once the lab is complete you have successfully collected 120 grams of substance X. What is your error and percent error?

Error = Difference between theoretical and yield. 150 - 120 = 30

Percent Error = $\frac{150-120}{150}$ = 20%

3. How many teaspoons are in a cup?

$$1 \text{ cup x } \frac{16\ tablespoons}{1\ cup} \text{ x } \frac{3\ teaspoons}{1\ tablespoons} = \frac{48\ teaspoons}{1\ cup}$$

4. If I need 4 tablespoons of a substance, how many cups do I need? How many mL?

$$4 \text{ tablespoons x } \frac{1\ cup}{16\ tablespoons} = 0.25 \text{ cups (or } \tfrac{1}{4} \text{ cup)}$$

$$4 \text{ tablespoons x } \frac{14.79\ mL}{1\ tablespoon} = 59 \text{ mL}$$

CHAPTER 5

1. If you required 6 mL of NaOH to run your titration, how many grams of NaOH will be required to make biodiesel out of 0.5 liters of waste oil?

6 mL + 5.5 mL = 11.5 grams/ Liter

2. If you required 5 mL of KOH to run your titration, how many grams of KOH will be required to make biodiesel out of 0.5 liters of waste oil?

5 mL + 7 mL = 12 grams/ Liter

$$\frac{12\ grams}{1\ liter} \text{ x } 0.5 \text{ liters} = 6 \text{ grams}$$

3. It is important to account for the purity of the base. If the purity of your NaOH from question 1 is 90% how many grams per mL do you actually need?

$$\frac{6\ mL}{0.90} = 6.67 \text{ mL}$$

6.67 mL + 5.5 mL = 12.17 grams/ Liter

4. It is important to account for the purity of the base. If the purity of your KOH from question 2 is 95% how many grams per mL do you actually need?

$$\frac{5\ mL}{0.95} = 5.26 \text{ mL}$$

5.26 mL + 7 mL = 12.26 grams/ Liter

CHAPTER 6

Fahrenheit to Celsius (____°F – 32) x = ____°C

1. Room temperature is typically around 70°F. What is that in Celsius?

70 – 32 = 38
$38 \times \frac{5}{9} = 21.1$°C

2. Step 1 of the lab requires you to heat the solution to 40°C. What is that in Fahrenheit?

40°C x $\frac{9}{5}$ = 72

72 + 32 = 104°F

CHAPTER 7

$$\text{Density} = \frac{Mass}{Volume}$$

1. At the end of the density lab you put 1.00 mL of your biodiesel into a 10.31 gram test tube. When you mass the test tube once the 1.00 mL of biodiesel has been added it has a mass of 11.16 grams. What is the density of your biodiesel?

11.16 grams – 10.31 grams = 0.85 grams
$\frac{0.85\ grams}{1\ mL}$ = 0.85 grams/mL

2. Do double check your density if you decide to calculate the density of the total amount of biodiesel you have. Your 100 mL beaker has a mass of 51.6 grams. You add 50 mL of biodiesel and now your beaker has a mass of 96.1 grams. What is the density of your biodiesel?

96.1 grams – 51.6 grams = 44.5 grams
$\frac{44.5\ grams}{50\ mL}$ = 0.89 grams/mL

$Q = MC\Delta T$
Specific heat of water = C = 4.18 J/(g*°C)
1000 grams = 1 kg
1000 J = 1 kJ

1. How much heat is released by a container of 500 mL of water if it cools by 10 degrees Celsius?

Q = heat = ?
M = mass (g) = 500 grams
C = specific heat = 4.18 J/(g*°C)
ΔT = Change in temperature = -10 °C

$Q = MC\Delta T$
Q = (500 grams) x (4.18 J/(g*°C)) x (-10 °C)
Q= -20900 J
20,900 J of heat was released as the water cooled.

2. 100 mL of water is heated from 24 °C to 28.5 °C over the span of 4 minutes. How much heat was put into the water?

Q = heat = ?
M = mass (g) = 100 grams
C = specific heat = 4.18 J/(g*°C)
ΔT = Change in temperature = (28.5-24) = 7.5 °C

$Q = MC\Delta T$
Q = (100 grams) x (4.18 J/(g*°C)) x (7.5 °C)
Q= 3135 J
3135 J of heat (energy) was absorbed by the water. This is also known as 3.135 kJ of heat.

3. In the scenario above a mystery fuel was burned to heat the water. The weight of the container and the fuel before burning was 247.8 grams and after burning the weight was 247.7 grams. What is the energy density of the fuel?

3.135 kJ of heat was absorbed by the water (based on the question above).

Change in mass is 247.8-247.7 = 0.1 grams. This means 0.1 grams of fuel was used/burned.

$\frac{3.135\ kJ}{0.1\ grams}$ = 31.35 kJ/gram

Pre-Lab Questions

1. What variable will you test for this lab? If choosing option 1, what is the variable provided? If choosing option 2, pick a variable that you are interested in testing.

2. How will you be sure to control all other factors that are not being tested? What variables need to be controlled and how will you keep them the same between the testing groups?

3. Why is it important to control for as many other factors as possible when performing the experiment?

4. What data will you collect during the experiment? Essentially, what will allow you to know if the variable you tested had any impact?

Experimental Design Worksheet

Group Name:____ Date:____________

Partners: ____

Hypothesis (Testable statement):

Control:

Variable (Manipulated variable):

Materials:

Procedure:

Data (Include Chart and Graph):

Results: Did your data support your hypothesis? Why or why not? What factors could have been possible sources of error in this experiment? What could you do to improve the design, data collection, etc. from your experiment and increase the validity of your results?

Student Copy

Activity Title: Soybean Seed Germination

Suggested Grade Level: High School

Time: 7-12 Days (class periods)

Skills Assesed: Comprehension of plant growth
Process of Photosynthesis

Anticipated AgEd Outcome: Plants and Animals for Food, Fiber, and Energy
Science, Technology, Engineering, and Mathematics

Materials Needed:

- An egg carton
  - 1 Styrofoam
  - 1 Cardboard
- Tap Water
- Soybean seeds
- Graduated cylinders (10 mL and 100 mL)
- Light source
- Top soil or any other type of dirt/potting mix
- A ruler or tape measure
- Other materials dependent on student procedures

Introduction

While some plants can reproduce asexually or by producing clones, many other plants produce seeds through sexual reproduction. For these plants, survival depends on germination of seeds and viability of young plants. If a seed germinates in the wrong place, at the wrong time, or under the wrong conditions, then life is over for that individual. In this lab, student groups will design and conduct experiments on seed germination to explore the effects of abiotic and biotic factors on plant survival. Plants require certain factors to grow successfully. They need abiotic factors such as water, light, nutrients, a substrate to grow in, and a suitable temperature. If these are not optimal for a plant, then its ability to germinate and grow can be diminished. Plant development can also be affected by biotic factors such as the age of the seed, predation or mold growth. For this particular experiment, students will seek to understand the impact of one biotic or abiotic variable on seed germination and growth. When designing and running their experiments, care should be taken by students to control all other variables except one.

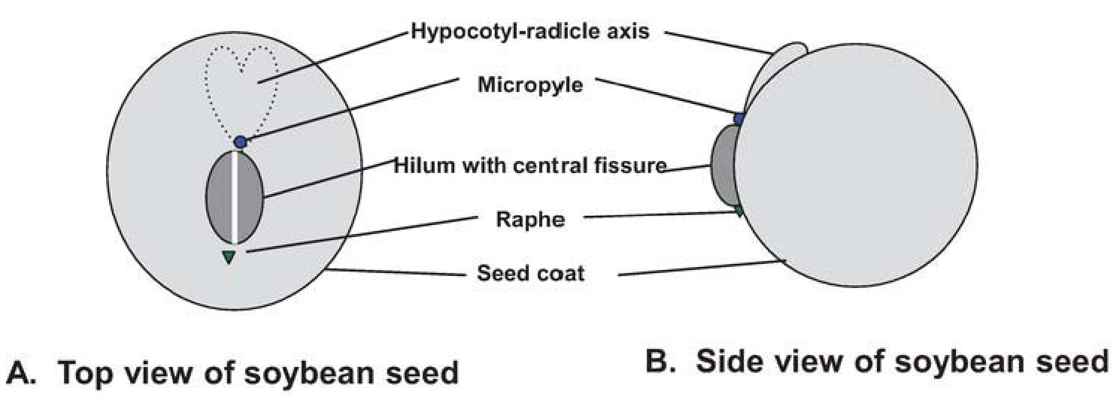
Set-Up Option 1: Testing Different Egg Cartons

1. Fill all 12 divots in the styrofoam egg carton half of the way with dirt. Press down on the dirt to form a pocket to place the soybean seed into, then place the soybean seeds on top of the dirt (one per divot).
2. Cover up the seeds with dirt until the dirt reaches approximately ¾ of way to the top of the divot walls. Make sure that none of the seeds are visible.
3. After the seeds are all covered, water each of the 12 divots with 15 mL of water.
4. Then place the carton either by a window or under another light source, like a heat lamp.
5. Repeat steps 1-4 with the cardboard egg carton.
6. Water every seed in both the cardboard and styrofoam cartons each day with 5 ml of water after the first day they are planted. Alternatively, water 10 mL every other day or 15 mL over a weekend if necessary.
7. Repeat this watering process for a week or until desired growth period has been reached.
8. Measure and compare the growth of each seed to one another. Take the height of each divot and compare the overall size and amount of growth (e.g., leaf size).

Set-Up Option 2: Student Direction Independent Variable

Follow the same set-up, but make sure to use the same material for the egg cartons (either both cardboard or both styrofoam). Students will create and design their own experiment testing a variable of their choosing. Examples Below:

- Test the impact of light exposure by placing one carton in a well lit area and one in a dark area (e.g., direct vs. indirect sunlight or covered vs. non-covered).
- Test the impact of soil pH by adding 1 mL of vinegar to the water used to one egg carton and just regular water for the other egg carton.



Post-Lab Questions

1. Did the variable you test result in any changes when it came to the soy bean plants?

2. How would you explain any difference noticed between the control and experimental group? If there was no difference, attempt to explain why no difference was seen between the two groups.

3. Soybeans, and really most plants, are not grown in egg cartons. What would the variable you tested look like in a more typical growing location (such as a large farming field)?

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Univeristy of Findlay Marketing and Communication. “Lab Students.” Photograph.

WASTE to ENERGY

Teacher Resource

The Waste to Energy teaching resource was envisioned as a way to catalyze novel pedagogy in the classroom for middle and high school students and foster STEM literacy in ways that excite and engage those students. The importance of renewable energy both environmentally and economically is becoming more apparent in the 21st Century, as are the skills associated with in-demand industries. Workforce development in agriculture, energy, and transportation is essential not only to solving our nation's technological needs but is critical to sustainable growth and domestic security. The Waste to Energy resource represents a way to introduce STEM concepts and skills, tied to workforce development, that prepares students for both their future careers and to be good citizens making environmentally responsible choices. The 11 Chapters contained within provide a number of hands-on, experiential learning activities focused on soybeans and the production of biodiesel, all of which align to Ohio State Science and Agriculture teaching standards. This resource also gives a variety of strategies and tips for educators on how to effectively teach STEM concepts to their students.

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