PHILADELPHIA ORCHARD PROJECT

GETTING FUNKY WITH FERMENTATION

Disclaimer: The nutritional information contained within is intended to educate individuals about diet and a healthy lifestyle approach. No advice provided is intended to diagnose, cure, or prevent any disease; or be construed as a substitute for medical attention or advice. Individuals with a specific medical condition or concern should seek advice from a physician. All fermented products present potential health risks. Individuals are responsible for assessing the safety of consuming fermented foods.

Lesson Title: Getting Funky with Fermentation

Topic: Preserving spring / summer harvests through lactic fermentation, featuring orchard herbs

Ages/Grade Level: 6-12

Subject Area: Food Science; Foodways & Traditions; Nutrition; Entrepreneurship; [School-adapted lesson from POP Core 3]

Materials:

- Sourdough bread
- Bottles of fruit-kombucha
- Sauerkraut
- Sample cups and spoons
- Cutting boards
- Sharp chopping knives
- Big mixing bowls
- Plastic gloves
- Estimating for 12 students (scalable)
  - 1 flat of pint size mason jars
  - 8 lbs cabbage
  - Ginger root
  - Oregano (*Origanum vulgare*) / thyme (*Thymus vulgaris*) / Bee balm (*Monarda didyma*) (harvested from orchard understories)
  - Sea Salt
  - Measuring spoons
- POP photo-guide that accompanies lesson
- POP-prepared handout with recipe

Prep Time: 10 minutes to set up food preparation station

Lesson Time: 60-75 minutes

- 5-10 minute ice breaker and taste-testing of fermented food products
- 20 minute info on background of sauerkraut, showing of pictures, discussion of the scientific process of fermentation and discussion of nutritional benefits
- 30 minute knife safety demo, making sauerkraut, adding in orchard herbs, and packing into jars and labeling
- 5 min rapid fire recap - students sharing one thing they learned from the lesson (creating connections between students' sharings)

DESIRED RESULTS

Established Goals:

- Students will identify some fermented foods, describe the process by which vegetables and fruits become fermented, and learn fermentation as one preservation method they might use to extend the harvest of their garden or orchard.
- Students will gain hands-on experience making sauerkraut as a potential value-added product for school-based CSA programs and learn to adapt it using culinary herbs of the orchards like thyme (*Thymus vulgaris*), oregano (*Origanum vulgare*), bee balm (*Monarda didyma*).
- Students will observe scientific processes by making and observing sauerkraut age such as ***maceration, osmosis, anaerobic respiration, alcoholic fermentation, and lactic acid***

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fermentation.

Standards:

11.3.9A Explain how scientific and technological developments enhance our food supply (e.g. food preservation techniques, packaging, nutrient fortification).
11.3.9G Analyze the application of physical and chemical changes that occur in food during preparation and preservation.
11.3.12G Analyze the relevance of scientific principles to food processing, preparation, and packaging.

Understandings…
Students will understand that…
What specific understandings about them are desired? What misunderstandings are predictable? What are the big ideas?

- There are **several methods of food preservation** we can use for preserving or extending our seasonal harvest: *drying, refrigeration, canning, freezing, brining, pickling, and fermenting*.
- **Fermentation** is a **metabolic process** that consumes sugar in the absence of oxygen -- producing organic acids, gases, or alcohol. Fermented foods often have **flavor characteristics** related to the process of fermentation they've undergone - including sharp, sour flavors, effervescence, carbonation, or 'fizz.'
- **Fermentation occurs in fruits, bacteria, yeasts, fungi, and in mammalian muscle.**
- Fermentation occurs naturally but **humans have used and controlled the process.** It has been used in the production of **alcohol** from fruit or grains, **kombucha** from tea and sugar, **vinegar** from alcohol, **yogurt or kefir** from milk, **sauerkraut** from cabbage, and other food and industrial products like **sourdough bread, cheese, and olives**.
- Fermented foods boast many benefits -- they are teeming with beneficial health-promoting **microbes called probiotics**. **When regularly eaten, these foods improve the population of good microbes in the gut**.
- Foods may be more digestible than when

Essential Questions:
What provocative questions will foster inquiry, understanding, and transfer of learning?

- What are some food preservation methods we can use to preserve food from season to season?
- What is fermentation?
- What is the chemical reaction that occurs during fermentation?
- What flavor characteristics does the fermentation process give to foods?
- How do temperature, pH, and time influence the outcome of fermented foods?
- What benefits or purposes does food fermentation offer?
- How does the health of our digestive system influence the body's immune system?

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raw because bacteria has already digested some of the sugars, and carbohydrates.	

Students will know…
What knowledge will students acquire as a result of this unit?
 	
- Fermentation is one of the oldest, most affordable, food technologies used all over the world for food preservation.
- In addition to the nutritional benefits of being rich in **probiotics** (microorganisms) that boost the **microbiome** of the gut and can improve digestion, fermented foods have an extended shelf-life.
	Students will be able to…
	What key skills will students acquire as a result of this unit?
	
	- Students will gain hands-on skills such as:
	  - safe and effective knife use,
	  - culinary literacy skills -- ability to follow and execute a recipe,
	  - critical thinking skills (understanding and brainstorming potential complications / concerns when fermenting food,
	  - teamwork,
	  - and observation skills as students check the progress of their fermenting sauerkraut along with the controls of time, temperature, and pH.

LEARNING PLAN

Background Info

Fermentation is the one of the oldest technologies used for food preservation worldwide. It has evolved over centuries through **cultural traditions** and **new technologies**. In areas where preservation techniques such as **cold storage** (refrigeration) or **hot-holding** of food cannot be used due to lack of facilities (fuel, electricity, and/or other resources) **fermentation can preserve food for extended periods of time.** Other benefits include: *addition of variety to the diet, an income-generating activity, nutritional benefits, and processing otherwise unusable raw materials.*

Fermentation is defined as the desirable biochemical process of primary food products by microorganisms (fungi, bacteria, yeasts) and their enzymes. It is carried out to enhance properties such as **taste, aroma, shelf-life, texture, and nutritional value.** Fermentation often follows a sequence of other food processing operations, including *cleaning, grinding, soaking, salting, cooking, packaging, and distribution.*

Lactic acid fermentation is a natural process brought about by the **lactic acid** present in the **raw food**, or derived from a **starter culture**. It's particularly useful because the lactic acid bacteria has a pH less than 4.5 -- which provides good shelf-stability and prevents the replication of other pathogenic bacterias. *Leuconostocs* and lactic streptococci generally lower the pH to about 4.0 to 4.5 and some of lactobacilli and pediococci to about pH 3.5. The extent to which bacteria are inhibited depends on the organism, temperature, and amount of acid produced, and properties of the food.

French chemist Louis Pasteur first described lactic acid as the product of microbial fermentation in **1857**. He was working at the University of Lille where he was asked by a local distillery for advice concerning

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some fermentation problems. He discovered at the distillery that two fermentations were taking place -- a lactic one and an alcoholic one - both induced by microorganisms. He discovered the mechanism of how microbial lactic acid fermentation works and was the **first to describe fermentation as a "form of life without air."**

Anthropologists have found through chemical analysis of archaeological findings that lactic acid fermentation for food production dates to the Neolithic Revolution. Babylonian and Egyptian Cuneiform texts show proof of cheesemaking in hunter-gatherer societies that enabled herds-people to preserve dairy supplies.

Lactobacillus is the the genus of bacteria that converts six-carbon sugar molecules to two lactic acid molecules, storing the released energy into two ATP molecules through the process of **anaerobic fermentation (without oxygen).** The chemical equation is: C6H12O6 (sugar) > 2 ADP + 2Pi (lactic acid) > 2 ATP + 2H20 > 2 C3H603 (energy released). If oxygen is present in the cell, many organisms will bypass fermentation and undergo **cellular respiration. Anaerobic respiration** in plant cells and some microorganisms such as yeast **produces ethanol (alcohol) and carbon dioxide.**

Aerobic respiration, by contrast, is the chemical process in which energy is released from food substances such as glucose - a sugar that **REQUIRES oxygen.** Not to be confused with breathing, aerobic respiration happens inside the mitochondria (the powerhouse) of the cells and transforms glucose + oxygen > into carbon dioxide + water (+energy). Aerobic respiration makes large molecules from smaller ones. In plants, sugars, nitrates, and other nutrients are converted into amino acids that can make proteins -- allowing muscles to contract in animals, and aiding birds and mammals in maintaining constant body temperature. The chemical equation is C6H12O6 + 6O2 > 6CO2 + 6H2O.

There are several types of food products made through the processes of fermentation. Each is made slightly differently depending on the input and carry with them rich cultural traditions.

- **Textured vegetable protein (Japanese tofu, Indonesian tempeh)** -- made from beans or grains using mixed starter cultures of filamentous fungi, bacteria, and yeasts; the fungal mycelium keeps the food particles together in a sliceable cake, whereas various enzymatic breakdowns contribute to flavor and digestibility

- **Food flavoring sauces and pastes (miso, fermented cereal-fish shrimp pastes Philippine balao balao and burong dalag, protein hydrolysates)** -- high salt content made from protein rich seeds, fish, or fish byproducts . Uses combinations of filamentous fungi, yeast, bacteria, as well as fish intestinal proteolytic enzymes. Resulting peptides and amino acids produce savory flavors.

- **Lactic acid fermented preserved foods (Korean kimchi, sauerkraut, labneh)** - made from vegetables, grains, roots, beans as well as milk, meat, fish. Transformed into shelf-stable sour tasting products.

- **Alcoholic beverages (beers, wines, spirits, kombucha)** - made from sugary or starchy materials (fruit, grains) - using yeasts and occasionally bacteria for alcohol formation. Sour taste produced by lactic acid bacteria.

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- **Vinegars characterized by acetic acid content (ex. Apple cider vinegar, red wine vinegar, rice wine vinegar),** made from various alcoholic products using acetic acid bacteria - used as a food preservative and flavoring agent. Sour.

- **Breads or fermented cereal porridge made from grain meal or flour**, leavened by action of yeasts or yeast-lactic acid bacteria mixed populations **(sourdough, Nigerian ogi, Kenyan uji, Philippine puto, Indian dosas)**. Fermentation of bread dough contributes to texture, taste, and shelf-life of baked bread.

*++For the purpose of this lesson targeted to school garden and orchard programs, **we'll focus on lactic fermentation of vegetables** (teachers might choose to work with cabbage (sauerkraut), carrots, turnips, radish or other root crops and incorporate herbs from the orchards as flavorings).++*

The common denominator of lactic fermentation of vegetables (in addition to fish or meat) is **salt (**kitchen salt or rock) added in varying quantities (1-25% w/w). **Many lactic acid bacteria have a better tolerance to salt than most pathogenic bacteria.** It also protects the product from spoilage bacteria. Through the process of **osmosis (**process by which molecules of a solvent tend to pass through a semipermeable membrane from a less concentrated solution into a more concentrated one thus equalizing the concentrations on each side of the membrane), salt also draws out the fermentable plant sugars. *Students can witness this as they add salt to the cabbage and see the extracted juice forming at the bottom of the bowl.*

Lactic acid fermentation of cabbage and other vegetables is a common way of preserving fresh vegetables in the western world, China, and Korea (where it is a dietary staple). Sauerkraut originally came from China, where it was brought over to Europe by the Tatars and built upon the original Chinese recipe fermenting it with salt instead of rice wine. It has since spread to many areas of the world - where it took root in Central and Eastern European cuisines becoming *zuurkool* in the Netherlands, *chucroute* in France, and sauerkraut in Germany meaning "sour cabbage." It's a popular condiment in savory pancakes and on top of hot dogs or bratwurst.

The raw vegetable is sliced or shredded and approximately 2 percent salt is added. The salt extracts liquid from the vegetable, serving as a substrate for the growth of lactic acid bacteria. Anaerobic conditions should be maintained, so the fermenting cabbage/herbs should be left to ferment in a **crock,** an earthenware ceramic lidded container, or in a **sealed jar.**

Recipe & Process:

- Instruct students on kitchen and knife safety. Wash and sanitize hands and all materials that will come in contact with food. Distribute food-safe gloves.
- For a 1-gallon container (16 half-pint mason jars - each student filling their own jar), finely chop 5 pounds of fresh cabbage (red or white). Measure our 3 TB of pickling salt (kosher or sea salt). Scale according to student group.
- Add the chopped cabbage to a large mixing bowl(s) and sprinkle with salt. Have students crunch the cabbage, massaging the salt into the chopped vegetables to see the extraction of juice.
- Allow the cabbage to sit salted for 5-10 minutes.

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- Feel free to incorporate fresh-harvested, chopped orchard herbs to flavor fennel seed 2 TB: 5 lb cabbage (sweet licorice flavor), 2TB oregano / bee balm / thyme : 5 lb cabbage (resinous, herbaceous flavors).
- Stuff into clean sanitized jars. Tip: use the large outer leaves of the cabbage as a barrier between the shredded cabbage and the metal circular lids. Have students press out all the air bubbles. Shredded cabbage should be submerged under the lid to keep shredded material under the brine and in an anaerobic condition.
- Place fermenting jars in a cool place (40-50 degrees)- ideally on a plate or a baking dish to catch any brine drips.
- Allow to ferment for a week - check 'doneness' in anywhere between 7-14 days. Temperature will impact fermentation window - hotter temperatures will make fermentation much quicker. Kraut should become tender in texture and sour to taste.
- When tested and kraut is to your desired taste, store sealed jars in the fridge or process in a water bath to seal the jars. Put packed jars with lids in a boiling pot of water - simmer 15 minutes for pint jars.

Orchard Herb Add-Ins: *Use in small quantity to add herbal flavor to kraut.*

Thyme (*Thymus vulgaris*): a perennial mint family plant with small leaves and white flowers. Contains rosmarinic acid and thymol which provide sharp, herbaceous flavor when added to food.

Oregano (*Origanum vulgare*): a perennial herb in the mint family with oval leaves. Rich in volatile oils - also contains thymol. A powerful antioxidant.

Bee Balm (*Monarda didyma*): a perennial, pollinator-friendly herb with bright scarlet flowers. Fragrant like a floral oregano. The flowers or leaves may be incorporated into culinary dishes - adding great flavor.

Fermented foods can offer incredible health benefits. Peer reviewed studies on sauerkraut found them to be a l**ow-calorie and mineral rich food** with **high quantities of lactic acid, vitamins A, B, C, and K.** Studies also found sauerkraut to possess chemopreventive activity (fighting cancer cells) and helpful for the body's uptake of iron. Sauerkraut was linked to healthy **digestive flora** linked to **healthy digestion and bowel movement**s. In addition to high levels of **tyramine and glucosinolates, sauerkraut also contained high levels of histamine** which stimulate allergic response and is to be **used cautiously for those who suffer from allergies.**

Intro (10-20 minutes):

- **Teacher establishes context for the lesson: today we're going to discuss food preservation techniques for preserving the harvest.**
  - Follow up questions: *what have you been growing / harvesting from your orchard / garden? What are your favorite ways to enjoy these fruits / vegetables?*
- **ASK**: *what are some ways we can extend the shelf-life of fruit / vegetables / herbs?*
  - (Students share responses: *canning, freezing, drying, etc)*,
  - Follow up questions: *What if we were in a location that didn't have fuel or electricity to cook?*

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- *What are some low-impact methods we might use*?
- **Introduce fermentation.** Ask students: *what is fermentation? (Students share responses). Can you name some fermented food products?*
- **Teacher shares background -- culturally and chemically -- on fermentation as one of the oldest food preservation techniques used worldwide.**

Opening/Hook

- Sample different fermented foods (passing out sample cups). Teacher can ASK:
  - *What are the ingredients you observe in each of these prepared foods?*
  - *What transformation did the ingredients go through?*
  - *What do you observe in terms of flavor or characteristics of these foods? What do they have in common? How are they different?*
- **Teacher establishes fermentation as a method we can employ to preserve the harvest, enhance the flavor and nutrition of foods from our school gardens / orchards.**
- **Fermented foods can become value-added products we can make for school CSA programs / entrepreneurship tie-in.**
- **Fermented foods are cultured foods. Discuss ways fermented foods are also part of the ecosystem of that garden / place.** Example: wild fermented foods contain yeasts and bacteria from the space in which they are made - adding to the unique character of these foods. Groups of people in adapting the foods might also share 'starter cultures' with each other - bringing those yeasts, bacteria, fungi from many regions into the culture of that initial starter. Example: sourdough starters made and cultivated for many years.
  - **Additional article tie-in:** https://trib.com/news/state-and-regional/newcastle-woman-maintains--year-old-sourdough-starter/article_000fcb17-5a5a-5590-84c2-3b55bb1d80fa.html

Lesson / Activity (20 -50 minutes):

The Plan/Procedure/Lesson Activities

- Teacher will share content related to the **history / chemical processes behind fermentation.**
- Teacher will **divide students up into groups to begin to assemble the sauerkraut.**
  - **Harvest and wash vegetables and herbs from garden space. Demonstrate safe use of cutting tools (clippers, scissors).**
  - **Discuss hygiene and safe knife practices.**
  - **Discuss processes of maceration, osmosis, aerobic and anaerobic respiration. Ask students:** *what do you observe as the salt is added to the jars? What other flavors / herbs might you consider adding?*
  - **Have students pack and label sauerkraut jars.**
  - **Have students make predictions about relationship between temperature and speed of fermentation.**
    - **Additional tie-in:** Teacher can establish experiment where fermenting jars are stored in different places of the classroom (full sun, shade, under desks, refrigerator). Have students take temperature readings of the space and pH strip readings of the sample jars over the course of 7-14 days. Graph observations.

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Conclusion (5 minutes):

Wrap up and Reflection

- **Rapid fire recap:** Have students share one thing they learned, teacher using each students' sharing to build to review the larger concepts discussed during the lesson and activity.
- **Brainstorm other ferments that can be made from the garden / orchard.** Explore the phytochemistry of the plants proposed and what form of fermentation might best suit each suggested one
- ***What questions remain? What else do you desire to learn about this topic?***

ASSESSMENT EVIDENCE

Performance Tasks:
Through what authentic performance tasks will students demonstrate the desired understandings? By what criteria will performances of understandings be judged?

- Students will be actively involved in the process of harvesting herbs (and / or vegetables) and making sauerkraut.
- They will observe the transformation of the raw material into a fermented product by observing the souring of the raw materials, the release of gas.
- Students will taste their product after 7-14 days and can be involved in the experimenting and graphing of results (as suggested above).

Other Evidence:
Through what other evidence (e.g. quizzes, tests, academic prompts, will students demonstrate achievement of desired results?
How will students reflect upon and self-assess their learning?

- Classroom teacher can continue to engage with proposed lesson -- having students observe and track the process of fermentation.
- Students can collect data on temperature and pH controls.
- Students tracking weather can suggest rates of fermentation if they were to make products in other regions or conditions.

ADDITIONAL ACTIVITIES & RESOURCES

Extensions/Adaptations/Game
What can the teacher do after the lesson to reinforce learning? Is there a complimentary extra activity if there is extra time?

- Investigate the body process of digesting food and the role of probiotics in digestion.
- Research the history of natural fermentation through human history.

Lesson Resources and/or Credit for Adapting

Wild Fermentation by Sandor Katz

https://www.learningzonexpress.com/media/wysiwyg/documents/worksheets/STEM-410241-lessons.pdf

http://www.who.int/foodsafety/publications/fs_management/fermentation.pdf

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- Explore fermented foods by region of the world or by primary ingredient - how are these foods prepared and what is the history? - Interview community members about different traditional foodways and fermented foods they grew up eating. Collect and experiment with recipes. - Research ways food manufacturers keep fermented foods safe and fresh through innovations in food packaging.	http://www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_21c/life_processes/energyrev3.shtml https://www.ncbi.nlm.nih.gov/books/NBK234703/ https://en.wikipedia.org/wiki/Sauerkraut https://www.culturesforhealth.com/learn/recipe/ https://www.almanac.com/content/how-make-sauerkraut https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4268643/ https://www.schooliseasy.com/2017/05/biology-lesson-teach-kids-yeast-fermentation-food-projects-part-1-bread-kimchi-sauerkraut/