FOOD Ed.

FOOD EDUCATION FOR CHANGE

UNIT 2: FOOD AND THE ENVIRONMENT

L.18

SOIL HEALTH

Note to Teachers

Healthy soil is central to sustainable farming. As the Stone Barns Center farm director Jack Algiere notes, a farmer farms soil. But why is soil so important and what is healthy soil? Both parts of Lesson 18 address this question.

There are many ways to approach soil analysis. We could order a chemical analysis from a local laboratory. It would provide a snapshot of the chemical components of the soil at that moment. Increasingly, however, farmers are focusing less on soil chemistry and more on soil biology—the analysis of the soil microbiome. The first part of the Lesson 18 approaches soil through simple chemistry, while the second illustrates the importance of soil biology.

Goals *In this lesson, students will*

- begin to appreciate the critical importance of soil.
- begin to understand the role of the soil microbiome.

Objectives

- Students will approach the topic of soil biology through a hands-on exercise and a reading.
- Students will conduct a series of simple soil tests to understand basic soil chemistry.
- Students will consider the soil microbiome through a reading and discussion.
- Students will apply their understanding of the microbiome to "solve" a farm mystery.

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Please use this margin to notate how to best adapt this curriculum to your students.

Materials

- A bag of sample soil, or soil from different locations. If possible, one should be a garden or farm.
- Distilled water, vinegar, baking soda (and/or pH test strips)
- Small clear plastic cups and jar
- Coffee filter cone and paper filter
- Rubric and reading

PART I: SIMPLE SOIL SCIENCE

Preface:

Soil sits at the heart of sustainable practice. Conventional agriculture has led to the degradation of soil across the world; sustainable farming demands that we cultivate and maintain good soil.

All soil is not alike. It varies on the basis of geography, geology, local biology and land use. As a result, all carrots, broccoli, tomatoes and other products of the soil are also not alike. The USDA describes carrots, for example, as a good source of Thiamin, Niacin, Vitamin B6, Folate and Manganese, and a very good source of dietary fiber, Vitamin A, Vitamin C, Vitamin K and Potassium. Yet, the carrot will not contain those nutrients if the soil does not provide them.

Students tend not to realize that crops get their nutrients from the soil around them. If the soil is degraded, it cannot supply those nutrients to what should be a nutritious food. The following simple tests are designed to help students understand some characteristics about soil and what can make soil healthier for the foods that grow in them. This lesson will take at least two days to complete.

Instructions:

1. Distribute attached rubric and let students know that they will be examining some basic characteristics of soil. Please let the students know where your soil sample(s) came from.
2. Ask students to put some soil in a cup. Not much is needed (1/4 cup is ample). They will work systematically to identify a number of soil traits, and should take notes as they go, on the rubric.

   Use the notes below to walk your students through this exercise.
3. Soil Contents:

   Observe the soil. What do you see? Sticks, rocks, leaves? Other recognizable contents? Note on the handout what you see in the soil.

   Remind students that soil is a mixture of organic matter (more or less decayed), minerals and organisms that live in it.
4. Soil Color:

   Is the soil darker or lighter? Does it have a tinge of color?

   Darker soil generally has more organic matter in it, and therefore tends to be more nutrient rich soil. Copper-rich soil can be bluish, while iron-rich soil can have a red hue.

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5. Soil Aggregates: Blow lightly on the soil, and then more heavily.

   Does the soil blow away? What would happen to field of soil like this on a windy day?

   Clumps are aggregates. They form from the byproducts of bacteria and fungi in the soil.

   Does your soil have clumps? Not only are clumps a sign of active bacterial and fungal life, but it means that your soil is less likely to blow away on a windy day.

6. Soil stability: Take a clump of soil and put it in water. What happens to it? Does it dissolve or hold together?

   Stable soil will hold together, indicating a strong structure that is protective against erosion by water. Stable soil will also absorb and hold water better, meaning that it can use rain or irrigation water more effectively.

7. Soil Composition:

   What is the soil composed of? Soil can be comprise a combination of three components: sand, silt and clay.

   Soil components are categorized generally by size:

   Sand: coarse, gritty. It is too coarse to hold water or nutrients.

   Silt: lighter than sand, but can erode easily. Feels smooth.

   Clay: fine, dense and heavy. Tends to feel sticky. Packs when it dries, preventing air, bacteria and other organisms from penetrating the soil.

   Loam describes the three components in ideal proportions: roughly equal amounts of sand and silt with a smaller amount of clay.

   Ask students to rub dry soil between their fingers. How would they describe this soil?

8. Ribbon test.

   Put just enough water on your soil to create a ball. Squeeze the ball between your thumb and forefinger to create a ribbon.

   If you can't form a ribbon, the soil is at least 50% sand and has very little clay.

   If your ribbon is less than 2 inches long before breaking, then your soil has roughly 25% clay

   If 2 to 3 1/2" long, roughly 40% clay

   If longer and if it doesn't break when you pick up the ribbon, it is at least 50% clay

9. Soil pH—the very rough method

   There are two easy ways to test soil pH. The simplest uses vinegar and baking soda.

   This test will give relative results.

   a. Vinegar: Take a sample of dry dirt (about 1/4 cup), mix with distilled water to make a liquid "mud" and then start pouring household vinegar over top. If the mixture fizzes, it's alkaline with a pH of over 7.5
   Free carbonates in the soil react with the acid at 7.5 or higher.

   b. Baking soda: Mix dry dirt and distilled water as above then start sprinkling baking soda over top. If the mixture bubbles, it's acidic, and the pH is less than 5.0.

c. If neither test produces a reaction, you have fairly neutral soil.

The ideal soil pH for most plants is 6.5 to 7.5.

10. Soil pH using pH test strip:

Place 1-3 T of soil in a small plastic or glass container.

Fill the container with distilled water to the same level as the soil sample.

Shake or stir vigorously for 1 minute. Then let sit for a minimum of 30 minutes before continuing.

Pour through a coffee filter into a second glass or plastic container to collect the liquid.

Dip the pH test strip into the liquid and compare the color on the chart provided by the manufacturer.

11. Step back at this point and ask students gauge students' experience with this exercise. Recognize that, for some students, the idea of "dirt" is so powerful that manipulating soil in their hands is unpleasant. Acknowledge their responses, while noting that one of the goals of these lessons is to re-shape their attitudes toward soil.

12. For curious students, understanding why these tests are important matters.

Return back to the question of soil pH to help make the importance of soil chemistry more clear:

Ideal soil pH is close to neutral (roughly 6.5 to 7.5).

An alkaline or acidic soil limits plants' ability to take in available nutrients.

Although nitrogen, potassium, and sulfur are relatively less affected by soil pH, phosphorus, the second most abundant element in the human body, is directly affected.

Phosphorus is mostly found in bones and teeth, but is also necessary for the growth and repair of tissues and to produce DNA and RNA. It also helps to absorb other nutrients like Vitamin D and zinc.

In soils more alkaline than 7.5, phosphate ions bond with calcium and magnesium to create a less soluble compound.

In acidic soils, phosphate ions react with aluminum and iron to form less soluble compounds.

Micronutrients like selenium, iodine, and zinc, which are substances we need in trace amounts, are less available when soil pH is above 7.5

So pH is linked to nutrient availability. Crops lose their ability to transmit nutrients to us when the soil environment prevents them from making these nutrients available.

13. Close this part of the lesson by opening the floor for comments and questions, taking the time to highlight important ideas.

PART II: THE SOIL MICROBIOME

1. **FOCUSD FREE WRITE #1:** Jack Algiere, Stone Barns Center's farm director, tells us that a farmer needs to farm soil. What in the world do you suppose he might mean by that statement?
Share responses. Students may have specific ideas about how to farm soil,

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but more importantly, this FFW exists to introduce the idea that good crops come from good soil. Care for the soil not only produces good, healthy food, but also enables a farm to survive in the long run.

2. If your students have been to our farm or another farm, much of this information is review. Introduce or remind students of the following common practices to promote and sustain soil fertility:

   - Crop Rotation: In a crop rotation system, the field is divided into plots and plant families are planted in a systematic rotation to ease the burden that a single crop would otherwise place on the soil. The field at the Stone Barns Center is on a seven-year rotation cycle.

     For example, if members of the nightshade family (tomatoes, peppers, eggplant) are planted in a given plot this year, they will not be planted in that same plot for another seven years.

     While conventional farming generally grows one crop over and over on the same land, leading to degraded soil, this method allows soil to recover and become rejuvenated, balancing the demands on soil nutrients.

   - Compost: Compost feeds the soil. It provides food for soil organisms and microorganisms. Farmers at Stone Barns Center make compost from organic matter from the field and woodlands as well as from animal manure. The soil around long-lived plants like trees is fed with a compost tea—a liquid, nutritionally rich supplement made by steeping compost in water.

   - Cover crop: We also plant a cover crop as part of the seven-year cycle, between rows during the growing season and during the winter on many plots. Cover crops help to protect the soil from erosion, and many cover crops return nitrogen back to the soil.

   In summary, plants take their nutrients from the soil, so farmers need to restore nutrients to the soil in order to maintain its fertility.

3. If we really want to keep our soil healthy, however, we need to understand more about the soil.

   To begin, I want to tell you a story:
   A few years ago, the Stone Barns Center field director Jason Grauer noticed that some of the tomato plants were being attacked by hornworm caterpillars. These insects eat the leaves and can quickly defoliate a tomato plant.

   Jason spent the day and a sleepless night worrying about what to do. He didn't want to lose the tomato crop, but Stone Barns farmers do not apply chemical pesticides.

   But when he came back in the morning, the problem had been taken care of: Wasps are one insect that parasitizes the caterpillar. It lays its eggs on the caterpillar, and the larvae feed on the hornworm. The larvae kill the hornworm by slowly devouring it.

   But this story isn't about caterpillars, wasps, or tomatoes—it is about soil and what is happening below ground. And by the time we finish, you will understand why.

4. Distribute the reading, an excerpt from an Atlantic Magazine article "Healthy Soil Microbes." Ask student to read it silently, underlining key words and phrases.

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5. When students have completed the reading, give them a series of short writing prompts:

   FFW #2 (3 minutes): On the basis of what you have read, what is soil?

   FFW #3 (3 minutes): What does it mean to keep soil healthy?

   FFW #4 (3 minutes): How does healthy soil support the crops that grow on it?

6. Open discussion of what students have read and their thoughts on it. The goal of this conversation is to understand how alive the soil is and understand that it is a community of organisms (sometimes called a "superorganism")

7. Close the discussion by testing students' comprehension of what they have just read. Ask your students: What is the secret to understanding the fate of the caterpillars?

   Make sure they understand that soil fungi enabled the tomato plants to react as a superorganism, and that the chemical signal they collectively released attracted the wasps, and therefore solved the caterpillar problem.

   In other words, nature works in amazing ways. If we listen to nature, we have the capacity to use its abilities to support good farming and good food.

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SQUASH ON TOAST

16 students

This recipe should be doubled for a class of 16. Use one type of squash for one group and another for the other group. This recipe is meant to help compare varieties of squash using the same recipe.

Equipment List

- Oven/toaster oven
- 2 medium bowls
- Parchment paper
- 2 baking sheets that fit into the oven/toaster oven
- Oven mitts
- 2 trivets
- 2 flat walled skillets
- 2 burners
- 2 mixing spoons
- 2 forks for smashing (or other utensil to smash)
- 4 spoons to spread cheese and top with mixture
- 2 wet measures
- 2, ½ teaspoons
- 2 teaspoons
- Bread knife
- 2, ½ cup dry measure
- 2 Tbsp
- 8 cutting boards
- 8 knives
- 8 peelers
- 2 compost bowls

Food Items

- 2, 2 1/2 – 3 pound kabocha or other yellow-fleshed squash (make sure to have two varieties of squash)
- Olive oil
- 1 tsp dried chili flakes
- Salt
- 2 yellow onions
- ½ cup cider vinegar
- ½ cup honey
- 8 slices of bread or crackers (something to taste both versions)
- 1 cup ricotta cheese
- Coarse salt
- Fresh mint

L.18 Rubric

HEALTHY SOIL

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TEST	OBSERVATIONS
SOIL CONTENTS	
SOIL COLOR	
SOIL AGGREGATES	
SOIL STABILITY	
SOIL COMPONENTS—TEXTURE (SILT, SAND)	
SOIL COMPONENTS—RIBBON TEST (CLAY)	
SOIL PH	

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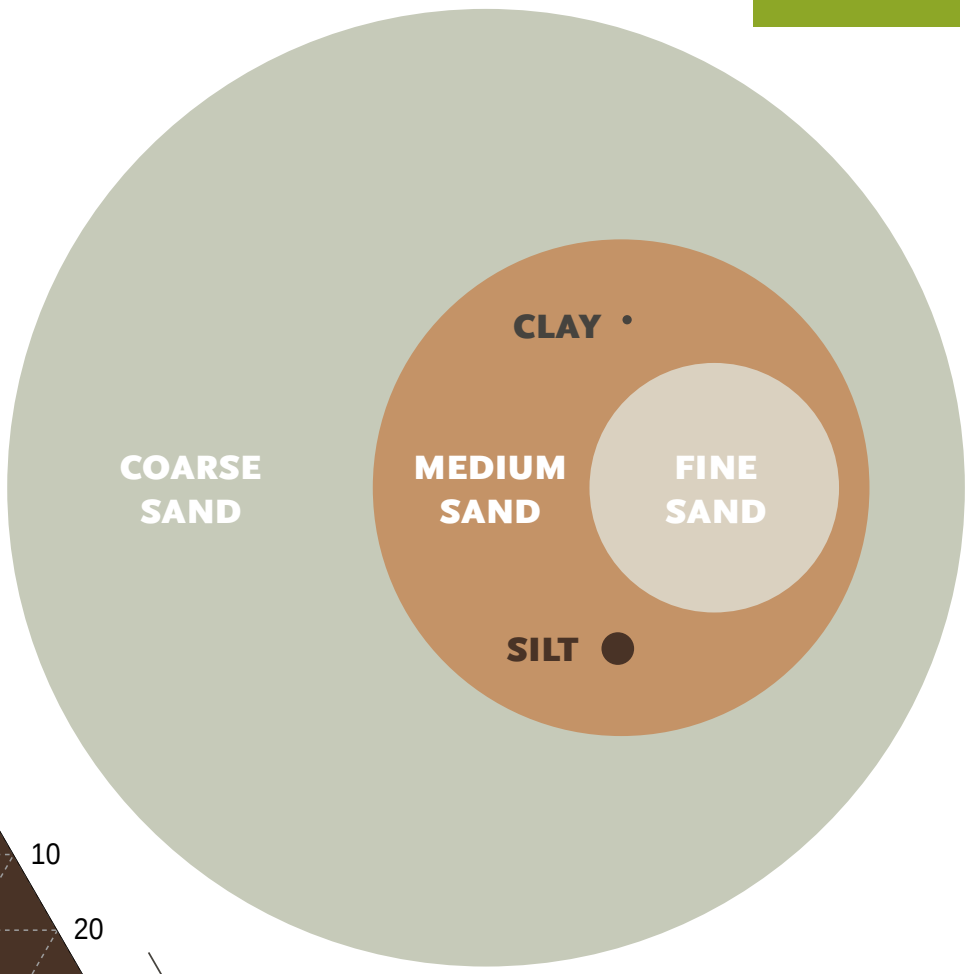
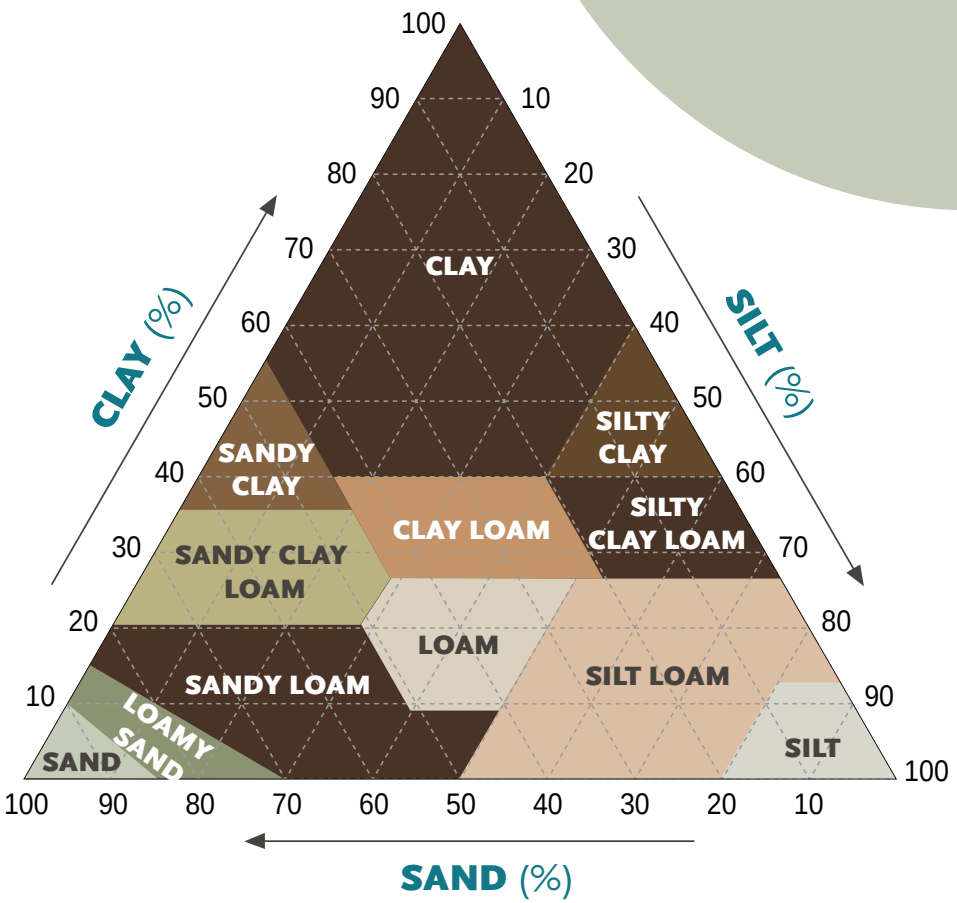
HEALTHY SOIL

Comparative sizes of sands, silt, and clay.





L.18 Reading

HEALTHY SOIL

MIKE AMARANTHUS AND BRUCE ALLYN
from
HEALTHY SOIL MICROBES, HEALTHY PEOPLE

The Atlantic Magazine June 11, 2013. https://www.theatlantic.com/health/archive/2013/06/healthy-soil-microbes-healthy-people/276710/

A small pine tree grown in a glass box reveals the level of white, finely branched mycorrhizal threads or "mycelium" that attach to roots and feed the plant. (David Read)

Just as we have unwittingly destroyed vital microbes in the human gut through overuse of antibiotics and highly processed foods, we have recklessly devastated soil microbiota essential to plant health through overuse of certain chemical fertilizers, fungicides, herbicides, pesticides, failure to add sufficient organic matter (upon which they feed), and heavy tillage. These soil microorganisms—particularly bacteria and fungi—cycle nutrients and water to plants, to our crops, the source of our food, and ultimately our health. Soil bacteria and fungi serve as the "stomachs" of plants. They form symbiotic relationships with plant roots and "digest" nutrients, providing nitrogen, phosphorus, and many other nutrients in a form that plant cells can assimilate. . .

These soil microorganisms do much more than nourish plants. . . [S]oil microorganisms both digest nutrients and protect plants against pathogens and other threats. For over four hundred million years, plants have been forming a symbiotic association with fungi that colonize their roots, creating mycorrhizae (my-cor-rhi-zee), literally "fungus roots," which extend the reach of plant roots a hundred-fold. These fungal filaments not only channel nutrients and water back to the plant cells, they connect plants and actually enable them to communicate with one another and set up defense systems. A recent experiment in the U.K. showed that mycorrhizal filaments act as a conduit for signaling between plants, strengthening their natural defenses against pests. When attacked by aphids, a broad bean plant transmitted a signal through the mycorrhizal filaments to other bean plants nearby, acting as an early warning system, enabling those plants to begin to produce their defensive chemical that repels aphids and attracts wasps, a natural aphid predator. Another study showed that diseased tomato plants also use the underground network of mycorrhizal filaments to warn healthy tomato plants, which then activate their defenses before being attacked themselves.

Not only do soil microorganisms nourish and protect plants, they play a crucial role in providing many "ecosystem services" that are absolutely critical to human survival. By many calculations, the living soil is the Earth's most valuable ecosystem, providing ecological services such as climate regulation, mitigation of drought and floods, soil erosion prevention, and water filtration, worth trillions of dollars each year. . .

With regard to stabilizing our increasingly unruly climate, soil microorganisms have been sequestering carbon for hundreds of millions of years through the mycorrhizal filaments, which are coated in a sticky protein called "glomalin." Microbiologists are now working to gain a fuller understanding of its chemical nature and mapping its gene sequence. As much as 30 to 40 percent of the glomalin molecule is carbon. Glomalin may account for as much as one-third of the world's soil carbon—and the soil contains more carbon than all plants and the atmosphere combined.

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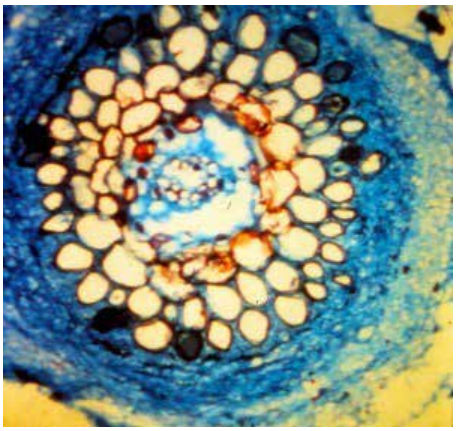

A mycorrhiza or fungus root in cross section. The stained-blue tissue is fungal.

An electron micrograph of a mycorrhiza with radiating mycorrhizal fungal filaments.

We are now at a point where microbes that thrive in healthy soil have been largely rendered inactive or eliminated in most commercial agricultural lands; they are unable to do what they have done for hundreds of millions of years, to access, conserve, and cycle nutrients and water for plants and regulate the climate. Half of the earth's habitable lands are farmed and we are losing soil and organic matter at an alarming rate. Studies show steady global soil depletion over time, and a serious stagnation in crop yields. . .

So, not only have we hindered natural processes that nourish crops and sequester carbon in cultivated land, but modern agriculture has become one of the biggest causes of climate instability. Our current global food system, from clearing forests to growing food, to fertilizer manufacturing, to food storage and packaging, is responsible for up to one-third of all human-caused greenhouse-gas emissions. This is more than all the cars and trucks in the transportation sector, which accounts for about one-fifth of all green house gases globally.

The single greatest leverage point for a sustainable and healthy future for the seven billion people on the planet is thus arguably immediately underfoot: the living soil, where we grow our food. Overall soil ecology still holds many mysteries. What Leonardo Da Vinci said five hundred years ago is probably still true today: "We know more about the movement of celestial bodies than about the soil underfoot." Though you never see them, ninety percent of all organisms on the seven continents live underground. In addition to bacteria and fungi, the soil is also filled with protozoa, nematodes, mites, and microarthropods. There can be 10,000 to 50,000 species in less than a teaspoon of soil. In that same teaspoon of soil, there are more microbes than there are people on the earth. In a handful of healthy soil, there is more biodiversity in just the bacterial community than you will find in all the animals of the Amazon basin.

We are making good progress in mapping the soil microbiome, hopefully in time to identify those species vital to soil and plant health, so they can be reintroduced as necessary. There is now an Earth Microbiome Project dedicated to analyzing and mapping microbial communities in soils and waters across the globe. We do not want to find ourselves in the position we have been with regard to many animal species that have gone extinct. We have already decimated or eliminated known vital soil microorganisms in certain soils and now need to reintroduce them. But it is very different from an effort, let us say, to reintroduce the once massive herds of buffalo to the American plains. We need these tiny partners to help build a sustainable agricultural system, to stabilize our climate in an era of increasing drought and severe weather, and to maintain our very health and well-being.

L.18 Lab

HEALTHY SOIL

SQUASH ON TOAST

Adapted from Jean-Georges Vongerichten's Squash on Toast by Mark Bittman

16 students

Ingredients

- 1, 2 ½ to 3 pound kabocha or other yellow-fleshed squash, peeled, seeded and cut into 1/8 to ¼ inch thick pieces
- ½ cup olive oil
- ½ teaspoon dried chili flakes, more to taste
- 3 teaspoons kosher salt
- 1 yellow onion, peeled and thinly sliced
- ¼ cup apple cider vinegar
- ¼ cup honey
- 4 slices bread, cut 1 inch thick
- ½ cup ricotta cheese
- Coarse salt
- 4 tablespoons chopped mint

Directions

1. Heat the oven to 450. Combine the squash, ¼ cup olive oil, chili flakes and 2 teaspoons of salt in a bowl and toss well. Transfer the mixture to a parchment-lined baking sheet and cook, stirring every few minutes, until tender and slightly colored, about 15 minutes. Remove from the oven.
2. Meanwhile, heat ¼ cup olive oil over medium-high heat. Add the onions and remaining teaspoon salt and cook, stirring frequently, until the onions are well softened and darkening, at least 15 minutes. Add the vinegar and honey, stir and reduce until syrupy and broken down, again at least 15 minutes or so. The mixture should be jammy.
3. Combine squash and onions in a bowl and smash with a fork until combined. Taste for seasoning.
4. Toast bread. Spread cheese on toasts, then top with the squash-onion mixture. Sprinkle with coarse salt and garnish with mint.