pH in Cooking

Unit: Culinary Science

Problem Area: Food Science

Lesson: pH in Cooking

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. **Define pH and the pH scale.**
2. **Summarize how pH values impact food preparation.**
3. **Summarize the pH risks associated with food preparation tasks.**

Resources. The following resources may be useful in teaching this lesson:

"Acids, Bases, and pH," *About.com: Chemistry*. Accessed Oct. 1, 2011. <http://chemistry.about.com/od/acidsbases/Acids_Bases_and_pH.htm>.

"The Alkaline Food Chart," *AcidAlkalineDiet*. Accessed Oct. 1, 2011. <http://www.acidalkalinediet.com/Alkaline-Foods-Chart.htm>.

Barham, Peter. *The Science of Cooking*. Springer, 2001.

"The Importance of pH in Food Quality and Production," *MBH Engineering Systems*. Accessed Oct. 1, 2011. <http://www.mbhes.com/ph_&_food.htm>.

Joachim, David, Andrew Schloss, and A. Philip Handel. *The Science of Good Food: The Ultimate Reference on How Cooking Works.* Robert Rose, 2008.

Lister, Ted, and Heston Blumenthal. *Kitchen Chemistry*. Royal Society of Chemistry, 2005.

Potter, Jeff. *Cooking for Geeks: Real Science, Great Hacks, and Good Food*. O'Reilly Media, 2010.

This, Hervé, and Jody Gladding (translator). *Kitchen Mysteries: Revealing the Science of Cooking*. Columbia University Press, 2010.

Equipment, Tools, Supplies, and Facilities

- ✓ Overhead or PowerPoint projector
- ✓ Visual(s) from accompanying master(s)
- ✓ Copies of sample test, lab sheet(s), and/or other items designed for duplication
- ✓ Materials listed on duplicated items
- ✓ Computers with printers and Internet access
- ✓ Classroom resource and reference materials

Key Terms.

The following terms are presented in this lesson (shown in bold italics):

- acid
- alkaline
- base
- botulism
- carbon dioxide (CO_2)
- coagulate
- connective tissue
- corrosive
- curdling
- deliming products
- enzymatic browning
- leavening
- mold
- neutral
- pH
- pH scale
- pathogens
- protein
- tenderizers

Interest Approach.

Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

> *Use a clear glass, and fill it with room temperature (or warmer) milk. Add a tablespoon or two of vinegar or lemon juice. Stir it and leave it alone for 30 minutes or longer.*

Ask students what they know about pH; you may have some responses regarding something related to acid. If no one knows or if the answers are generic, begin with basic facts regarding the pH scale of 0 to 14. For example, products with lower pH numbers are more acidic. Ask students to name some acidic foods.

After they have constructed a list of acidic foods, ask what is at the opposite end of the pH scale (alkaline foods). Then ask the students to name some alkaline foods. Follow this with a few questions regarding student knowledge of any benefits or risks related to cooking with foods that are acidic or alkaline. This should all be a general discussion.

End the discussion, and go back to the milk. Pour some of the contents of the glass or cup in a second glass or cup. The product will now be a thickened and a coagulated mess—a chemical reaction most students will not expect. Ask students what happened to the milk. What did the acid do, and how did it happen? Use this conduit as a graphic depiction of what can happen when cooking and not understanding how pH affects foods.

CONTENT SUMMARY AND TEACHING STRATEGIES

Objective 1: Define pH and the pH scale.

Anticipated Problem: What is pH, and how is it measured?

I. pH and the pH scale

A. ***pH*** is the level of acidity or alkalinity (base or basic) of a given product, based on a comparison scale.

1. Acids and bases are two extremes that describe chemical properties. Mixing acids and bases can cancel out or neutralize the extreme effects of both ends of the pH scale. A product that is neither acidic nor basic is neutral.
2. To a scientist, pH stands for “potential of hydrogen” and is used to determine if water and soil would allow a plant to attract and absorb hydrogen molecules based on each substance’s acid or alkaline level. Salt (NaCl) does not contain hydrogen. Therefore, salt has no pH until water or another liquid is added to it. Salt water has a pH between 7 and 8.

B. The ***pH scale*** is a system used to measure how acidic or basic a product is—whether food or cleaning product or environmental element. The scale is a linear measure from 0 to 14. ***Neutral*** (neither acid nor alkaline) is a pH of 7; pure water has a pH of 7. ***Acid*** is a pH of less than 7 (low numbers on the pH scale).

Alkaline (***base***) is a pH greater than 7 (high numbers on the pH scale). Acid and alkaline are chemical opposites. The pH scale is logarithmic.

1. Each whole pH value below 7 is 10 times more acidic than the next higher value. For example, a pH of 4 (tomato juice or honey) is 10 times more acidic than a pH of 5 (black coffee or bananas). The same is true for pH values above 7; each value is 10 times more alkaline than the next lower level.
2. Pure water is neutral until it is mixed with other chemicals. Then the mixture becomes acid or alkaline. For example, adding vinegar or lemon juice to water makes the new mixture an acid. In contrast, mixing liquid drain cleaner, ammonia, or bleach with water makes the new mixture a base.

C. pH in food is typically not measured using reactive paper or chemicals. Instead, the pH of ingredients is known in advance and is utilized by given pH levels. NOTE: pH values of food vary slightly, depending on the source of the information and the level of ripeness and/or state (e.g., fresh tomatoes or tomato juice) of the food.

1. As pH values at opposite ends of the scale are total chemical opposites, a reaction occurs when polar opposite substances are mixed.
2. A common reaction is the release of gas (carbon dioxide), with the result being the two opposites cancel each other out and neutralize each other during the release of the gas.

Teaching Strategy: *Use VM–A. Demonstrate the pH scale and the effect of adding water (dilution) by using the University of Colorado at Boulder physics website at http://phet.colorado.edu/en/simulation/ph-scale. Choose the "Run Now" version. Have students select a product (from milk to cola to spit) from the left tap and then add water from the right tap. Watch the middle pH scale change as the solution is diluted. You may empty the beaker using the bottom tap.*

A quick demonstration of the neutralization of an acid and base may be conducted. Mix baking soda (a base) with vinegar (an acid). A bubbling reaction occurs. The bubbles release carbon dioxide gas and neutralize the solution.

Objective 2: Summarize how pH values impact food preparation.

Anticipated Problem: How is the knowledge of pH used in cooking?

II. pH and food preparation

A. ***Carbon dioxide (CO_2)*** is a heavy colorless gas that dissolves in water to form carbonic acid and is the chemical in baked goods that causes them to rise (leaven) in the oven as the CO_2 gases are released. ***Leavening*** is the use of an ingredient (e.g., yeast, baking soda, or baking powder) to produce a gas that lightens a dough or batter. Typically, the reaction occurs when an acid and alkaline are mixed. (NOTE: The same concept is observed with some heartburn medications that result in a person burping a few minutes after ingestion. Burping is the release of the gas that indicates the acid is neutralized.)

1. Recipes that use baking soda (rather than baking powder) usually have an acid liquid as one of the ingredients—buttermilk, sour milk, or yogurt—to react with the soda and produce bubbles.
2. Recipes that direct a person to mix all the dry ingredients together and then add the liquid prevent the baking powder from reacting until nearer the end of the mixing.
3. Recipes that direct a person to mix just until the ingredients are combined or moistened minimize the escape of gases from the dough or batter. Stirring too vigorously or for too long may cause the chemical reaction (the release of CO_2 bubbles) to end before the baked good is placed in the oven.
4. Recipes that direct a person to add sugar (or another sweet substance) to bread dough feed the yeast. The CO_2 gas and alcohol created by the yeast eating the sugar give bread its light texture. The alcohol created by the yeast eating the sugar is burned off during baking.

B. Acids in food typically add a desirable tang or a sour flavor to the product. It is a crucial element in cooking when acidifying a mixture. Common acidic foods are:

1. Citrus
2. Vinegar
3. Sour cream
4. Buttermilk
5. Yogurt
6. Tomatoes
7. Wine
8. Pineapple
9. Sour candies

C. ***Tenderizers*** are food ingredients or chemicals that break down fibrous connective tissue in meats and meat products.

1. ***Connective tissue*** is the tough membrane that runs through and surrounds meats; it supports and binds together other tissues to form ligaments and tendons.
2. Most meat marinades include a tenderizer in the form of an acid (e.g., lemon juice or vinegar). Acid has the ability to break down (tenderize) the fibrous connective tissue in meats.
3. Salting (dry brining) also helps break down fibrous matter in meat, making it a common tenderizing technique.

D. ***Protein*** is a macromolecule made up of amino acids necessary for the body to function and is the basic component of skin, hair, muscle, enzymes, and antibodies. Most animal meats, seafood, eggs, dairy, grains, and beans contain protein. Acids have a direct affect on protein. Specifically, they ***coagulate*** (tighten) the spiral-shaped protein molecule. When a low pH acid is introduced into protein foods, coagulation occurs to some degree.

1. Acids strengthen the protein in flour to make stronger breads and batters.
2. Acids thicken some fat-based sauces. For example, heating butter over direct heat until very hot and then squeezing lemon juice into the hot fat results in a thickened pan sauce.
3. Acids bind eggs and beans together for long periods of hot holding before they separate.
4. Acids help keep protein colors intact. For example, eggs that get too hot or are held hot for too long may start to turn green. An acid mixed with the egg prior to cooking prevents this discoloration.

E. ***Pathogens*** are the microorganisms in food that can make people sick. To flourish, pathogenic microorganisms require several things (food, moisture, and warmth) and a suitable pH environment between 4.6 and 7.4.

1. By making the food item more acidic or more alkaline, these pathogenic bacteria are severely inhibited in their ability to grow.
2. Many alkaline substances tend to have a salty taste, so it is more common to use acids to adjust the pH level in foods as a tool to inhibit pathogens. For example, by squeezing lemon juice in a salad bound with mayonnaise (e.g., tuna or pasta salad), the pH level drops to a more acidic level, and the dish is more resistant to bacterial growth. As a result, the food is safer to eat.

F. Alkaline (base) agents react with and neutralize acid. As such, they may be intentionally added to achieve a more neutral taste.

1. Sugar is often added to a tomato sauce to “tone down” the acidic bite.
2. Baking soda (a strong alkaline substance) could be added to tomato sauce to neutralize the acid in tomatoes. The chemical reaction of giving off carbon dioxide would be visible, and the end result would be a mild, smooth tomato sauce with no added sugar.

G. Honey, molasses, and corn syrup are liquid sweeteners with a high acid level. These liquid sweeteners are often added to dry sweeteners (e.g., table sugar and sucrose) in cooked candy syrups to recrystallize the dry sugar and produce a standard candy texture. Hard candies can be turned into “brittle,” or aerated hard candy. The addition of baking soda results in a reaction with the acid in the sugar, and the bubbles stay in the candy, which makes it brittle.

H. Alkaline substances are commonly used as preservatives, typically in the form of salts. Alkaline substances slow the deterioration of protein, making it exceptionally useful in the production of foods (e.g., beef jerky, pickled meats as in corned beef, and canned foods).

I. ***Enzymatic browning*** is a process that occurs in some produce when a cut surface is exposed to the air (e.g., apples, bananas, and pears). A naturally occurring enzyme in these foods reacts with oxygen when the flesh is cut, turning it brown.

   1. Acids are extremely useful in slowing and preventing enzymatic browning in fruits and vegetables. This is commonly seen in cut apples, eggplant, and potatoes.
   2. Brushing the cut flesh with an acid (e.g., lemon juice or vinegar) interferes with the chemical reaction, preventing the browning. Many home cooks use this technique without knowing why, but it is a straightforward example of using pH as a tool in food preparation.

Teaching Strategy: *Use VM–B and VM–C.*

Objective 3: Summarize the pH risks associated with food preparation tasks.

Anticipated Problem: What pH risks are associated with food preparation tasks?

II. pH risks in food preparation

A. The ***corrosive*** (harmful or destructive) nature of acidic foods is a major concern when cooking.

   1. Acidic foods have the potential to break down the surface of soft metals—aluminum, copper, and cadmium—via contact. Cooking acidic foods in these types of metal pots and pans creates a potential health risk as the food absorbs metal that is actually dissolving from the pan.
   2. Evidence of this corrosive activity is visible when cooking lemon sauce in an aluminum pan. The sauce will eventually turn green as it absorbs the metal.

B. ***Deliming products*** are acids that remove the alkaline film and encrusted residue deposited on cookware and the heating elements of coffeemakers and dishwashers; they react with and break down the alkaline buildup.

   1. Cooking highly alkaline foods in cookware can result in discoloration of surfaces and/or leave a whitish film on those surfaces.
   2. To remove this film or deposit, an acid must be used. For instance, water that is considered "hard" is high in alkaline minerals, and coffeemakers are commonly coated in that dull white matter. Their performance slows as alkaline mineral deposits clog the heating element.

C. ***Curdling*** is the coagulation (tightening) of the protein molecule by an acid.

   1. The coagulation of protein in flour results in stronger flour for batters and dough.
   2. However, coagulation of protein also has negative affects (curds). For example, adding a strong acid (e.g., vinegar or lemon juice) to milk begins a chain reaction that coagulates or curdles the milk. This result is generally undesirable, leaving the product a lumpy mess.

D. ***Mold*** is a wooly microorganism in the fungus family, and it loves to grow in acidic environments. Citrus fruits and berries are good mediums for mold growth.

E. ***Botulism*** is the most deadly pathogenic food-borne microorganism. It is a spore-forming bacterium (*Clostridium botulinum*) that causes an acute paralytic disease caused by the botulin (a neurotoxin—a protein that acts on the nervous system—formed by botulinum) in food. This bacterium requires an acidic and oxygen-free environment in which to live and flourish. Cooking does not destroy the botulism bacterium, so prevention is essential. Canned foods, such as tomatoes, are the perfect growth medium due to the high acid level and the oxygen-free environment of the can.

   1. It is important to discard cans of acidic foods (e.g., tomato sauce and pizza sauce) that are deeply dented or bulging.
   2. Home canning of acidic foods should adhere to strict sanitary standards.

Teaching Strategy: *Assign LS–A through LS–C.*

Review/Summary. Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle. Questions at the ends of chapters in the textbook may also be used in the Review/Summary.

Application. Use the included visual master(s) and lab sheet(s) to apply the information presented in the lesson.

Evaluation. Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is provided.

Answers to Sample Test:

Part One: Completion

1. base
2. alkaline
3. copper, aluminum, or cadmium
4. baking soda
5. curdles
6. 7
7. carbon dioxide (CO_2)
8. mold

Part Two: Multiple Choice

1. c

2. a
3. b
4. c
5. c
6. b

Part Three: True/False

1. T
2. T
3. F
4. F
5. T
6. F
7. T
8. F
9. T

Sample Test

Name ______________________________

pH in Cooking

Part One: Completion

Instructions: **Provide the word or words to complete the following statements.**

1. Alkaline is also known as a/an _________________________.
2. A sauce with a pH value of 8.1 is considered to be _________________________ on the pH scale.
3. One of the metal cookware varieties to avoid when cooking an acidic food is _________________________.
4. The most common and most used ingredient added to make foods more alkaline is _________________________.
5. Milk _________________________ when an acid such as lemon juice is added.
6. Acid is a pH value less than _________________________.
7. A common reaction of opposite ends of the pH scale is the release of _________________________ gas, with the result being the two opposites cancel each other out and neutralize each other during its release.
8. A wooly microorganism in the fungus family that loves to grow in acidic environments is _________________________.

Part Two: Multiple Choice

Instructions: **Circle the letter of the correct answer.**

1. To change the pH of creamy coleslaw and make it safer from pathogenic bacteria, add _____.

   a. carrots
   b. mayonnaise
   c. cider vinegar
   d. pepper

2. Of these choices, the likely pH value of a tomato is _____.

   a. 5.1
   b. 7.0
   c. 9.0
   d. 11.9

3. Mold tends to grow on raspberries because raspberries are _____.

   a. alkaline
   b. acidic
   c. a fruit
   d. a fungus

4. Which of these statements is *true*?

   a. Acids tenderize protein foods.
   b. Alkaline substances help prevent enzymatic browning.
   c. The bacteria that cause botulism grow best in acidic environments.
   d. All of the above

5. Coffee pots may need to be delimed because the _____.

   a. coffee stains the pot
   b. coffee is acidic
   c. local water is alkaline
   d. None of the above

6. The reason acidic foods are not cooked in soft metal pans is because acids _____.

   a. are tangy
   b. are corrosive
   c. can change the color of the metal
   d. can make foods curdle

Part Three: True/False

Instructions: **Write *T* for true or *F* for false.**

_____1. Acids help break down connective tissue in meat.

_____2. In terms of pH, pure water is neutral.

_____3. Combining a strong alkaline and a strong acid in a recipe causes a reaction that changes the color of the food.

_____4. The pH scale is from 0 to 12.

_____5. Alkaline substances slow the deterioration of protein.

_____6. Alkaline substances strengthen protein.

_____7. Pathogens are microorganisms in food that can make people sick.

_____8. Discard cans of acidic foods (e.g., tomato sauce) that are deeply dented or bulging to prevent salmonella.

_____9. Salt does not contain hydrogen. Therefore, salt has no pH until water or another liquid is added to it.

pH SCALE EXAMPLES

ACID		
Battery acid 0		
Lemon juice	1	stomach acid
Vinegar	2	lemon juice
Orange juice	3	cola beverages
Tomato juice	4	honey
Black coffee	5	strawberries, cheeses
Milk, tea	6	saliva
Pure water	7	pure water
Sea water (salt water)	8	eggs
Baking soda	9	orange, tangerine
White bread	10	milk of magnesia
Ammonia solution	11	ionized water
Soapy water	12	navy beans
Bleach, lye, oven cleaner	13	spinach, tomatoes
Liquid drain cleaners 14		
ALKALINE		

NOTE: Examples of pH values vary depending on the source and the state of the food or other product. For example, bananas may appear on both the acid and the alkaline scales depending on ripeness. This is intended to be an overall view from acid to alkaline. Please review additional sources.

USES OF PH

- Acids help break down the connective tissue in various meats, making them tender.
- Acids, such as those from this citrus, add tang to foods, even candy!

- Alkaline substances preserve food, such as beef jerky.

- Acids strengthen the protein in flour to make stronger breads and batters.

- An application of an acid, such as lemon juice, would have prevented or slowed the enzymatic browning of this apple.

pH RISKS IN FOOD PREPARATION

- Soft metal cookware, such as copper and aluminum, should not be used to cook high-acid foods.

- Acid foods support mold growth.

- Lime scale on this heating element is due to high-alkaline levels in the water supply.

- Home canning of acidic foods should adhere to strict sanitation guidelines.

- Cottage cheese is formed when an acid is added to fresh milk, and the milk's protein molecules tighten and produce curds.

Name ______________________________

pH in Cooking Crossword Puzzle

Purpose

The purpose of this activity is to practice the terminology related to pH in cooking.

Objective

Identify terminology related to pH in cooking.

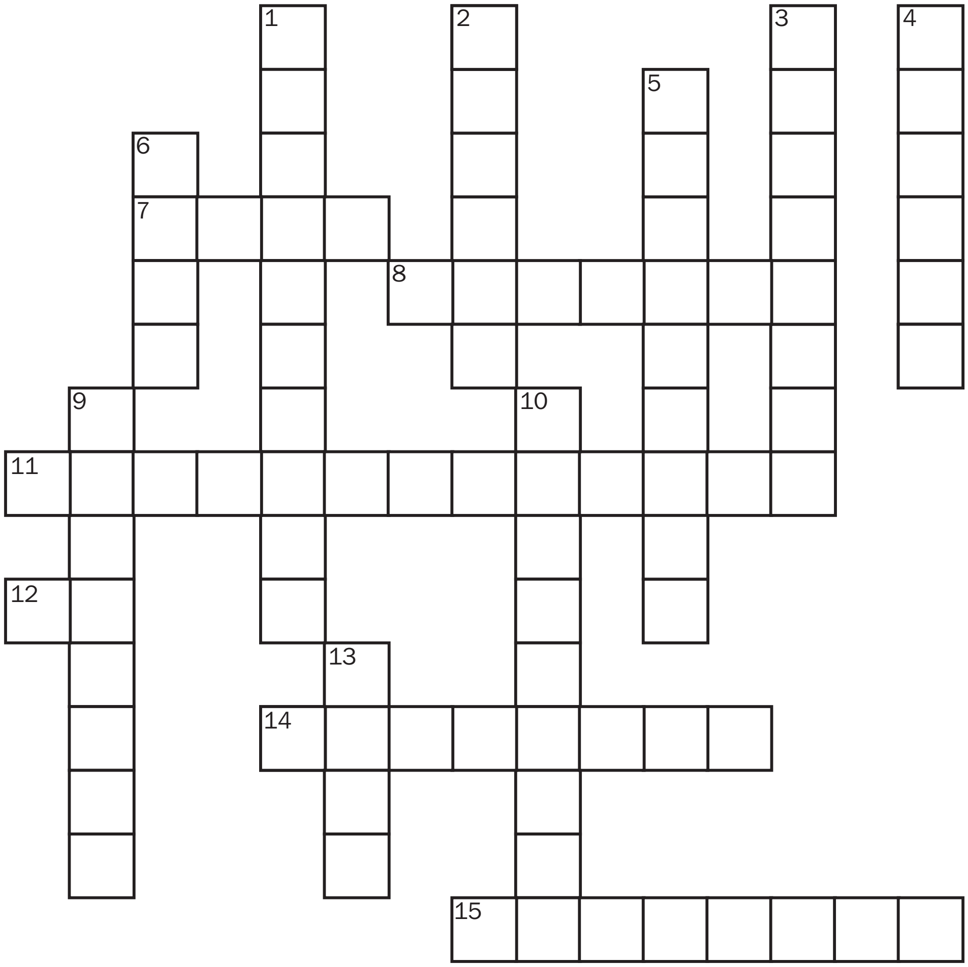
Materials

- lab sheet
- writing utensil

Procedure

1. Work independently.
2. Use the clues to solve the pH Crossword Puzzle.
3. Compare your solutions to those of classmates.
4. Participate in a discussion of the puzzle clues and solution.
5. Turn in your completed pH Crossword Puzzle to your instructor.

A puzzle about pH as it relates to cooking.



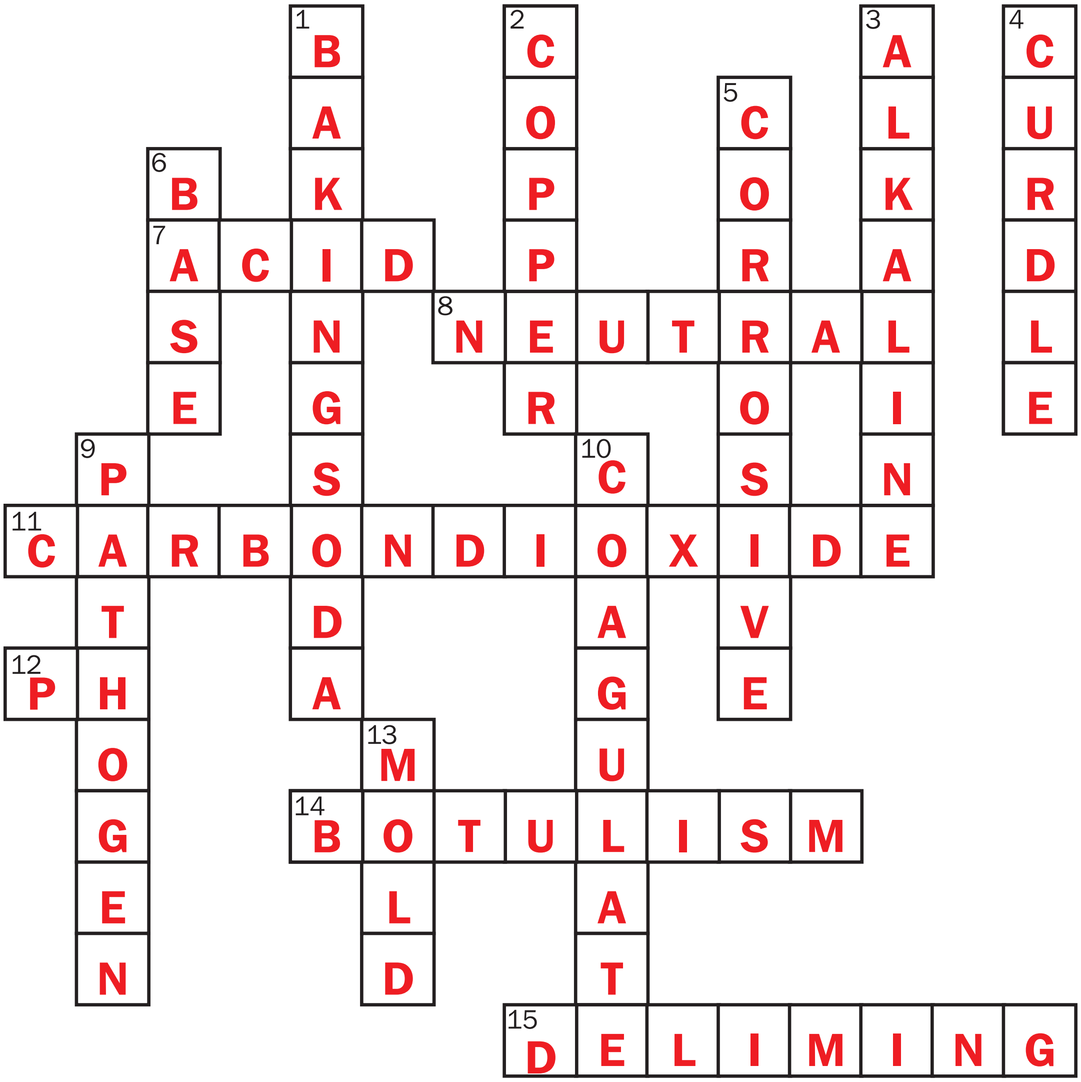
ACROSS

7 vinegar
8 water
11 strong acid and alkaline mixed together release this (2 Words)
12 potential hydrogen
14 deadly bacteria needs acid to
15 grow needed when alkaline deposits build up

DOWN

1 common alkaline for neutralizing acid (2 Words)
2 soft metal
3 pH level of 9.5
4 acid added to milk
5 the reason acid should not be used in soft metals
6 alkaline
9 acid slows their growth
10 proteins tighten
13 grows well on acidic surfaces

pH in Cooking Crossword Puzzle



Name ____________________________________

The Power of pH in Cooking

Purpose

The purpose of this activity is to apply the lesson content (along with further research as needed) and use it to answer three-dimensional problem-solving questions.

Objectives

1. Apply lesson content to solve pH-related cooking questions.
2. Research responses as needed to respond to each scenario.
3. Participate in a discussion of each scenario with your classmates and the instructor.

Materials

- lab sheet
- computer with Internet access
- reference books
- writing utensil

Procedure

1. Work independently to respond to the following cooking scenarios that involve pH. Each scenario requires you to apply your knowledge of pH in food. In many cases, you may have to conduct further research to fully respond to the problem. When needed, fully explain your rationale (reasoning). Respond with your solution in the form of a short paragraph.

   a. **Scenario 1:** Anthony is making his famous spaghetti sauce. After simmering all the ingredients for several hours, he added 2 tablespoons of baking soda (a generous amount), and the sauce got frothy and bubbly for several minutes. After the bubbles subsided, he tasted the sauce and added a tablespoon of salt. Anthony is very careful

not to over salt his famous sauce. However, baking soda is very salty. What would explain Anthony adding more salt to his spaghetti sauce?

b. **Scenario 2:** Soft metal pots and pans are inappropriate choices for cooking acidic foods, but what is left? Name two other types of cookware that could be used to cook acidic foods. Explain each answer.

c. **Scenario 3:** Acid coagulates protein molecules, including the protein in milk. Name three dairy products in which coagulation is desirable. Explain each answer.

d. **Scenario 4:** Tough cuts of meat are often marinated in mixtures containing salt and vinegar—opposite chemicals in the pH scale. Explain the benefits (to tough cuts of meat) of using an acid and alkaline in the marinade.

e. **Scenario 5:** Bella is making fresh crab salad. She wants to change the pH level of the salad and reduce the bacterial growth. Unfortunately, she has no lemons available. She has vinegar, but she thinks that would taste pretty nasty with crab. Name two other ingredients Bella could add to the salad to adjust the pH level.

Bella does have salt available, but she doesn't use it to adjust the pH level. Why not?

f. **Scenario 6:** Juan is making chocolate chip cookies. The ingredients are flour, granulated sugar, brown sugar, eggs, vanilla, salt, baking soda, and chocolate chips. The cookies puff up in the oven before flattening out when they cool. Clearly there was a reaction in the oven, and carbon dioxide was released. Which ingredients caused the reaction? Explain your choices.

g. **Scenario 7:** Mold grows well on high-acid fruits, but bread gets moldy too. How can that be? Explain your answer.

h. **Scenario 8:** Salt and baking soda are the most common alkaline additives for adjusting the pH values in food, but there are other alkaline substances available. Why aren't other alkaline substances used more commonly?

i. **Scenario 9:** A recipe for crêpes includes flour, milk, oil, eggs, granulated sugar, and vinegar. What is the purpose of vinegar in the crêpes? [HINT: Think carefully about the uses of an acid.]

2. Participate in a discussion of each scenario with your classmates and the instructor. Add any additional items you wish to remember about pH and cooking to your lab sheet.

3. Turn in your completed lab sheet to your instructor.

The Power of pH in Cooking

1. Answers may vary. Probable answers to each scenario are shown below.

   a. **Scenario 1:** *A reaction occurs (CO_2 bubbles) when an alkaline substance, such as baking soda, is introduced into an acidic solution. The result is a sauce that is neutralized. The acid and the alkaline become inert or chemically dead. In the process, the acid loses its "bite or tang," and the alkaline loses its salty taste. Anthony added salt because, following the reaction, the sauce was no longer acidic. Therefore, it had no residual salty flavor. If too much baking soda had been added—more than was needed to neutralize the acid—there would have been a salty taste left from baking soda that did not react.*

   b. **Scenario 2:** *Answers may vary. The obvious metal pot and pan source for cooking acids is stainless steel, which is a completely non-reactive metal. Tempered glass is also a good option and is non-reactive. Aluminum is a viable choice IF it has been coated with a non-stick surface, preventing the metal from being in direct contact with the acid. The downside with non-stick aluminum cookware is that stirring with any forceful contact with the surface may scratch the coating, ruining the pan and potentially putting coating particles into the food. Enamel cookware is a non-reactive product, but if it is scratched, the metal underneath will likely react to acids. Cast iron is highly reactive, but it should be noted that if the pan is coated with a non-stick surface, OR if it's well seasoned (a layer of burnt-on carbon), the reaction to acid is minimal if any. Scratching issues still apply.*

   c. **Scenario 3:** *The addition of an acid may ruin a sauce prepared with fresh milk. However, acid is an essential ingredient for the properly thickened and rich textures of buttermilk, yogurt, and sour cream. All cheese benefits from the addition of acid's coagulating properties (along with the enzyme rennin). Rennin coagulates milk to the point that the curds are formed, and the liquid whey separates from the curds.*

   d. **Scenario 4:** *There are two primary reasons that many marinade mixtures utilize salt and vinegar. The acid and the salt add flavor to the meat. In addition, the acid helps break down connective tissue but also tends to toughen the protein (tighten the protein spirals). To counteract the toughening caused by the acid (vinegar), salt helps break down the tough muscle (protein). Together, they are more effective than either is alone.*

   e. **Scenario 5:** *Answers will vary. Bella could use any citrus juice, not just lemons. She could use cream of tartar, which is a white tasteless acidic powder. She could use dry white wine that has a fair amount of acid. Bella could also add some tomatoes (including the juice) to lower the pH level. While most seafood salads include salt in the recipe, it is only enough for taste, not to raise the pH. Adding enough salt to make the salad alkaline enough to reduce bacterial growth of pathogens, the result would* *be that the taste would be far too salty. So salt is unsuitable for changing the pH in this instance.*

f. **Scenario 6:** *Baking soda caused the main reaction, especially when combined with brown sugar. Brown sugar has a reasonably high acid level, especially for a dry sweetener. Had all the sugar in the recipe been granulated sugar, the reaction would have been minimal at best and hardly enough for a good quality cookie product.*

g. **Scenario 7:** *Bread has a number of variables that affect mold growth. Mold spores are already present in the wheat flour, awaiting a favorable environment in which to grow and flourish. Any high moisture content encourages mold growth. So soft, moist breads (e.g., cinnamon loaf and Danish rolls) mold quicker than firm, dryer breads (e.g., French, Italian, and many artisanal loaves and rolls). Preservatives would inhibit mold growth, and salt would slow it. Unlike fruit, acids in breads actually serve to slow mold growth, as evidenced in sourdough bread. Sourdough breads will eventually mold, but slowly. Also, the high acid level in bread reduces mold growth.*

h. **Scenario 8:** *The best answer is that the majority of other alkaline sources are either within a food substance that is not viable for use in other recipes or that the alkaline source is toxic (i.e., ammonia and bleach).*

i. **Scenario 9:** *Crêpes are a tender product but also need enough strength to be flipped, handled, rolled, and plated without breaking or tearing—a tall order. The addition of an acid strengthens the protein in the flour and eggs to achieve this amount of handling.*

Name ______________________________

CO_2 Experiment

Purpose

The purpose of this activity is to create something to monitor the reactions when carbon dioxide is produced.

Objective

Prove that yeast produces carbon dioxide gas (CO_2).

Materials

- lab sheet
- writing utensil
- 1 1-qt. mixing bowl
- 1 large zip-type freezer bag (2 quart to 1 gallon size)
- 1 envelope of rapid-rise, active, dry yeast
- 1 c. (0.24L) lukewarm water (about 100°F or 37.7°C)
- ½ c. (0.12L) granulated sugar

Procedure

1. Collect all of the supplies and measure all of the ingredients. (Mise en place.) The last thing is to measure and test the temperature of the water.
2. In the bowl, mix the yeast into the lukewarm water. Combining the yeast granules with the warm water activates the yeast.
3. Add the sugar to the bowl and mix.
4. Pour the entire contents of the bowl into the plastic bag. Push out as much air as possible from the bag. Then seal it tightly.

5. Place the plastic bag in a warm place. Come back in about 1 hour. (If you have the opportunity to leave the bag for 2 hours, do the 1-hour check. Then come back in another hour.)

Observations:

1. How much has the bag filled with CO_2 gases? (¼, ½, doubled?)
2. Is the liquid full of CO_2 bubbles that the yeast has produced?
3. How many yeast cells do you think are contained in one package of dry yeast?

CO_2 Experiment

1. A yeast cell processes approximately its own weight in glucose (sugar) per hour.
2. Yeast produces CO_2 and ethanol (C_2H_5OH)—two molecules each—from the glucose ($C_6H_{12}O_6$).
3. There are billions of small yeast cells in one package of dry yeast.
4. There should be noticeable puffiness in the bag after 1 hour and definitely after 2 hours. If possible, one bag could be left overnight and viewed the next day. It will be very puffy.