adventures in food science

Water and Tissue Changes in Fruits and Vegetables

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ADVENTURES IN FOOD SCIENCE

Introduction

A few of the 6000-odd food items you buy in a modern supermarket are fresh. But most of them are processed — cooked, canned, waxed, dried, frozen, bottled, pickled, packaged, wrapped, baked, or changed in one way or another for your convenience. Just pause for a minute and think of all of the prepared mixes, instant foods and beverages, and frozen concentrates at the supermarket!

Yet, many of you feel if you are to buy, cook and eat a variety of these foods, they must look right, taste right and have the right texture. And more and more of you are demanding high nutritive value, too.

The demand for these qualities in the foods you eat holds true whether you cook, can and freeze food produced at home, or buy all of your food at a supermarket. Providing the qualities you demand in food — color, flavor, aroma, texture and nutritive value — is the task of scientists.

Before these processed foods come to the supermarket, scientists probe into their cells and tissues to determine their physical and chemical makeup; to find out the individual components that give them their characteristic color, flavor, aroma and texture; and to find out the kinds of nutrients they provide for us. Then they develop methods of cooking, canning, drying, freezing, storage, packaging and so on to preserve the desirable qualities in food or to change the characteristics you dislike.

Scientists investigate the enzyme, circulatory and respiratory systems of plant and animal cells and tissues to find out changes they undergo — when food is harvested, when it is shipped or stored, when it is cooked, or when it is canned, dried, frozen, or packaged or otherwise processed. They explore ways of controlling deterioration as these processes are applied. Scientists examine the microorganisms and microflora associated with and in food, and explore ways to prevent them from spoiling food.

And the nuclear age brought with it an entirely new field of science — atomic radiation. Scientists are now applying it to canned, packaged and fresh foods to prevent various forms of deterioration and spoilage. Another big new task for food scientists is developing special foods for people to eat on their trips in outer space.

These are only a few of the adventures the food scientist may pursue. They are probably enough, however, to impress you with the fact that science plays a big role in your food supply and in food quality, whether processed by a homemaker or by industry.

You can start some food science adventures today that may lead to a career in food science. Over 25 percent of all industries in the United States are related to food, either directly or indirectly. Just think of the career opportunities in such a huge enterprise! This calls for a whole battery of chemists, biochemists, physicists, microbiologists, food technologists, nutritionists, dietitians, engineers and others.

Or if you plan to be an up-to-date homemaker, you can start today to apply the findings of science in preparation and preservation of food. In this way you and your family are assured top quality food on the dining table.

This collection of science experiments will help you improve your cooking, canning and freezing now. These science adventures will help you decide whether you would enjoy a career in food science and technology.

Many people can help you with this adventure ... your county Extension agents, your home economics teacher, your school lunch supervisor, your science teacher, your public health nutritionist, and others.

The Purposes of Adventures in Food Science

• To provide you some experiments which may be used along with 4-H club and other projects.
• To produce some ideas that may be used as demonstrations and exhibits. (Don't forget to make colored photographs of your work.)
• To acquaint you with some scientific principles that may help you improve your use of food in everyday living.
• To introduce you to some career possibilities in the field of food science.
Water and Tissue Changes In Fruits and Vegetables

The texture of fruits and vegetables is highly prized in family meals. We expect each fruit or vegetable to contribute its own characteristic or unique texture to a meal. For instance, from tomatoes, watermelon or cantaloupe we expect a flesh that is soft, yet firm, but still full of juice. We expect from cucumbers a crisp, crunchy-hard flesh, but one that is also full of juice. We expect green beans to be tender and firm, but not tough. What hard-to-fill orders these are! Yet, fruits and vegetables easily meet these texture requirements in our bill of fare. How is this possible?

Scientists have probed the physical and chemical make-up of vegetables and fruits and discovered much about them. Their findings enable us to understand why vegetables and fruits provide the specific textural qualities we want most, how to preserve the qualities we like and how to modify those we wish to change.

In these experiments you will discover some physical and chemical properties of fruits and vegetables, and will learn how to preserve or modify them for greater acceptance, whether at the table or at the supermarket.

Experiment No. 1

Acids, Alkali and Green Vegetables

A. Purpose: To determine the effect of acid and alkali on the tissues of snap beans.

B. Equipment and Materials Needed

Measuring spoons
Measuring cups
3 saucepans (with lids or foil to cover) numbered 1, 2 and 3
1 1/2 cups snap beans, cut in 1 inch pieces
Vinegar
Baking soda
Slotted spoon
3 plates of same color, numbered 1, 2 and 3

C. Procedure

1. Wash snap beans well, and drain. Cut off tips at each end. Lay several beans together lengthwise and cut crosswise into 1 inch pieces.

2. Divide into 3 portions of 1/2 cup each.

3. Into each saucepan put water as below:
   No. 1—1 cup plain water
   No. 2—1 cup of water and 1/2 teaspoon of baking soda
   No. 3—1 cup of water and 1 tablespoon of vinegar

4. Cover each saucepan and bring to a rapid boil. Add sample of beans to each, cover, and return quickly to a rapid boil. (Takes only 1 to 2 minutes.)

5. Immediately remove cover and record time. Be prepared to add additional vine-
gar and water, or soda and water if the vegetables boil dry before the time is up.

6. Reduce heat and boil for 20 to 30 minutes.

7. With slotted spoon lift beans in saucepan No. 1 onto plate No. 1, and likewise samples 2 and 3.

8. Take pieces of beans from each plate and press between finger and thumb. Bite a couple of pieces from each sample.

9. Observe the color of each sample.

D. Questions

1. What effect does cooking have on fruits and on vegetables such as snap beans? Why? What takes place?

2. What effect does baking soda have on the cells and tissues of snap beans? Why? What effect does acid have?

3. What effect does baking soda (alkali) have on the color of green vegetables? What effect does vinegar (acid) have? What effect do the volatile acids have?

4. Why is it inadvisable to use baking soda (alkali) when preparing green vegetables for the family?

E. Conclusions

(From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions—Experiment 1
Experiment No. 2 – Water Changes in Fruit

A. Purpose: To determine the effect of sugar on fresh fruit.

B. Equipment and Materials Needed
   Measuring spoons
   Measuring cups
   2 cups strawberries, washed, capped and drained well, OR 2 cups fresh, fully ripened peaches, washed, peeled, sliced (1½ to 2 pounds fresh unpeeled peaches), OR 2 cups of watermelon cubes.
   1 sharp paring knife
   ¼ cup of sugar
   2 1-pint glass canning or freezing jars and lids, numbered 1 and 2.

C. Procedure
   1. If strawberries are used, rinse quickly in 3 changes of clear water, lifting berries a few at a time out of the water. Remove caps and drain in a colander or strainer (or spread out on newspapers covered with paper towels).
   2. If peaches are used, wash carefully and drain. Peel thinly. Cut in half lengthwise and remove seed. Slice each half 3 or 4 times, lengthwise.
   3. Place 1 cup of the fruit into container No. 1. Put lid on and refrigerate.
   4. A little at a time place 1 cup of fruit into container No. 2, sprinkling with sugar each time fruit is added. Put lid on and refrigerate.
   5. Record the time. Observe at 1 and 2 hour intervals. Then refrigerate and observe in 24 hours and again in 48 hours.

D. Questions
   1. What is meant by cell turgor? How is it maintained in fruits and vegetables? What happens when it diminishes or is lost?
   2. By what force or pressure is cell volume maintained? Explain this action or pressure.
   3. How does this force or action cause textural changes in the fruit in this experiment?

E. Conclusions

(From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions—Experiment 2
Experiment No. 3 – Water Changes in Vegetables

A. Purpose: To investigate the effects of salt solution on vegetables.

B. Equipment and Materials Needed

   Measuring spoons
   Measuring cups
   1 large kettle or saucepan for making brine a day ahead (Step 1 below)
   2 ½-gallon jars (preferably glass) or plastic containers (Go to a restaurant or school lunchroom and ask for large glass pickle jars.)
   2 cucumbers, green and of good quality
   2 stalks of celery
   2 crisp leaves of head lettuce
   Salt (ice cream or dairy salt preferred)

C. Procedure

   1. Make 10 percent brine by dissolving 1 cup (8 oz.) salt in ½ gallon of hot water. It may be necessary to heat the solution and stir to completely dissolve salt. Be sure solution is cool before adding to vegetables.
   2. Wash jars thoroughly with hot soapy water. Rinse and drain well, or dry.
   3. If purchased cucumbers are used, wash well with a vegetable brush, using cold water and detergent to remove waxy coating. Rinse well in clear water. Wash celery well with a vegetable brush, using plain water.
   4. Number the jars 1 and 2.
   5. Fill jar No. 1 with plain, cold water.
   6. Fill jar No. 2 with a 10 percent salt water solution.
   7. Place 1 cucumber, 1 stalk of celery and 1 lettuce leaf in each jar.
   8. Cover samples and set aside in a cool, out-of-the-way place.
   9. Examine the samples in 15-20 minutes. Examine in 1 hour. Remove lettuce leaves. Allow remaining samples to stand overnight. Remove vegetables and examine carefully, pressing and bending gently. Allow to stand overnight and repeat examination.

D. Questions

   1. How are fruit and vegetables structured or made up?
   2. How does the structure of plants change as they grow older? How does this affect eating quality?
   3. How does cell turgor affect or influence the texture of fruits and vegetables?
   4. What is the effect of the salt solution upon the cell turgor of the vegetables in this experiment?
   5. How does osmotic action operate in pickle making?

E. Conclusions

   (From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions—Experiment 3
Experiment No. 4
Syrup Impregnation of Fruit Preserves

A. Purpose: To investigate the effect of sugar syrup on kumquat or calamondin preserves.

B. Equipment and Materials Needed
   Measuring spoons
   Measuring cups
   1 saucepan
   1 slotted spoon
   3 plates, numbered 1, 2 and 3
   6 fresh kumquats, or calamondins
   1 cup sugar
   ½ cup water
   1 sharp pointed paring knife

C. Procedure
1. Wash and drain kumquats or calamondins. In 3 of the kumquats or calamondins cut a ¼-inch gash crosswise and through peel. Leave the remaining 3 as they are.
2. Place fruit in saucepan. Cover with water and bring to a boil. Cook 5 minutes. Drain.
3. Make a syrup of sugar and water. Add kumquats or calamondins. Bring to boil and cook 10 minutes.
4. Observe the fruit. Record any differences.
5. Cover and let stand overnight. Observe fruit and record any differences.
6. Cook again uncovered for 10 minutes and let stand overnight.
7. Observe fruit and record any differences.

D. Questions
1. How are the protective skins of fruits and vegetables structured?
2. How does this epidermal tissue protect fruits or vegetables?
3. What is turgor? How is cell turgor maintained?
4. How does osmotic force operate to maintain cell volume?
5. How does osmotic force operate in making preserves?
6. What effect did the ¼ inch gash have on the kumquat/calamondin preserves? Why?

E. Conclusions
(From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions—Experiment 4
Supplementary Notes

Leaves, edible stems and fruits are largely made up of parenchyma cells, whose walls are composed almost entirely of cellulose and pectin—a substance which serves to hold the cells together. Besides parenchyma cells, plants also are made up of conducting cells, supporting cells, and protective cells. Arranged in groups these form tissues, each of which performs a particular function in the plant.

Most fruits and vegetables consist largely of parenchyma tissue, which synthesizes, and stores carbohydrate. The conducting tissue forms long tubes through which water and salts or foodstuffs are distributed through the plant. Supporting tissues are composed of long pointed cells whose walls of cellulose thicken as the plant ages and become encrusted with lignin, a tough, woody material. Also present in some plants is a supporting tissue composed of cellulose and pectic substances in place of cellulose and lignin.

In young plants these supporting tissues are not numerous, nor are they hardened. However, as the plant grows older the nature of the cementing substances often changes, perhaps becoming encrusted with tough, woody hemicelluloses. As suggested earlier, lignins and other compounds are deposited, causing a thickening of cell walls.

This briefly explains why young vegetables and fruits have a tender, crisp, juicy texture, and why overmature or old ones may be tough, stringy, woody and otherwise undesirable as food. The degree of rigidity of structural tissues and cell walls contributes to the texture desired and expected of fruits and vegetables.

In addition to these factors which influence fruit and vegetable texture, the protective cells also play a role. Composed of specialized parenchyma cells closely pressed together, they form a tissue or skin on plant leaves, stems and fruits. This tissue or skin may be thin as in strawberries, tomatoes, nectarines, cherries and peaches, or may be thick and corky as in oranges and grapefruit. In either case, the skin usually contains stomata or small "valves" to permit respiration. In varying degrees this layer of epidermal tissue protects the organ from mechanical injury and also from insects, fungi and microorganisms. Once the skin is broken, the fruit readily spoils whether it has been harvested or not.

We do not know exactly what chemical changes occur when fruits and vegetables are boiled, steamed, canned, dried or frozen. It is evident numerous reactions occur, since profound changes in appearance, texture, flavor, and color take place. Studies of a limited number of fruits and vegetables indicate:

- After harvest, the cells of fruits and vegetables continue to live. When cooked, the cells are killed.

- In cooking, whatever the method used, all fruits and vegetables undergo softening. This results from changes in cellular structure, either through separation, rupture, or shrinkage, or by a combination of the pectic substances which cement cells together; separation of cells is the prevailing result.

- Under the mild conditions of cooking, little breakdown of the cellulose in cell walls and tissues occurs. When baking soda (alkali) is added to the cooking water, cellulose breaks down more rapidly and the texture of the quick cooking vegetables or fruits becomes soft and mushy. Some of the vitamins, particularly vitamin C and thiamine, are quickly destroyed if cooked this way. Therefore, you should never add soda when cooking vegetables or fruits for family use. Dilute acid, however, firms and toughens vegetable tissue.

- As suggested earlier the parenchyma cells of fruits and vegetables are separated by tiny pockets and passages of air. When these products are cooked or otherwise processed, changes in intercellular air occur. If a fruit or vegetable is simply heated, the intercellular air swells, forces the cells apart and causes cracks in the food. This is what happens in a baked potato or baked apple. As cell walls become more permeable, cell sap from the vacuole (see sketch on page 5 in Color in Foods, Chlorophyll) may escape into the intercellular spaces, causing a change in the appearance and juiciness of the food. Because of this, the chalky appearing surface of fruits or vegetables may change to translucence as the air is replaced by water. With further boiling a third change may occur. The discharge of air from intercellular spaces may lead to a filling of the space with the cooking water. With fruit preserves this may instead result in a ready impregnation with syrup.

In addition to the structural composition of cell walls and tissues, the turgor of the cell contributes texture to fruits and vegetables. Turgor is the pressure of the cell contents on its partially elastic wall which makes or keeps the wall rigid.

Look at the sketch of the cell on page 5 in Color in Foods, Chlorophyll and note the large part called the vacuole. This part of the cell is filled with a watery substance called the cell sap. This sap contains salts, sugars and other soluble materials dissolved in water. These materials inside the cell push outward on the cell walls just as air inside a balloon does. When
for some reason cell volume diminishes, the cell becomes soft and flaccid, somewhat as a balloon does when part of the air escapes. On the other hand, if volume increases beyond a point permitted by the elasticity of the cell wall, the cell wall ruptures, the cell contents flow out and rigidity is lost. While the fruit or vegetable is still part of a living plant, a delicate balance of forces maintains the cell at a normal volume, yet allows an inflow and outflow of liquids through the cell wall.

Maintenance of cell volume depends upon a force known as osmosis. And osmosis simply means that where two liquids, one or both of which carry some crystalline substance in solution, are separated by a suitable membrane there is movement of liquids through this membrane. This movement continues until both liquids have reached equilibrium, that is, they are both of the same density or concentration. The movement of liquid is always more rapid from the less dense or less concentrated to the denser or more concentrated liquid. The rate of movement is proportional to the difference in densities or concentrations.

How does osmotic force or pressure operate in a fruit or vegetable to maintain cell turgor? Plant cell walls are, for the most part, composed of cellulose, which is permeable to many types and sizes of molecules. Also, the membrane of protoplasm which may be stretched around the large storage vacuole in the cell, is semi-permeable. (See the diagram of a cell on page 5 in Color in Foods, Chlorophyll.) As suggested earlier, the vacuole in the cell contains salts, sugars and other soluble materials dissolved in water. If the fluid outside the cell wall is composed only of water or of a more dilute solution than in the cell, water will move into the cell through the permeable tissue and semi-permeable membrane making up the cell wall.

The effect of osmotic force or action on cell turgor may be seen when vegetables are placed in a concentrated salt solution or when sugar is sprinkled over strawberries, sliced peaches or other fruit. The water of the lesser concentrated fruit or vegetable juice passes into the higher concentrated salt or sugar mixture, cell volume diminishes, the cell becomes soft and flabby, and the cell wall loses its rigidity.

Success in making plump, tender fruit preserves depends upon application of the principle of osmosis in the following manner: Fruit is placed in a sugar syrup whose concentration is somewhat greater than the fruit juice. Then two things happen: (1) the fruit, especially if soft, becomes shrunken and flabby . . . because of the more rapid flow of the less concentrated fruit juice through the cell walls into the more highly concentrated syrup; (2) the syrup becomes less concentrated because it is diluted by the outflow of fruit juices. After some hours in the syrup, however, the fruit will resume its normal plump condition.

If the concentration of the syrup is increased by adding more sugar or by further cooking, and the fruit is again cooked in it, the same changes noted above will take place again. Repeating this by slow stages makes it possible to produce preserves having a sugar content of 65 per cent or even more.

If, however, at any of these stages (and especially at the beginning) the syrup is too concentrated, the flow of juice from the fruit may be so rapid as to rupture or collapse the cells in some fruits. Under these conditions osmosis will practically cease, and the highly concentrated syrup will only "draw" the juice from the fruit, leaving it shriveled and tough.

Success in pickling vegetables such as cucumbers, cauliflower and snap beans also depends upon osmosis. As soon as the vegetables are placed in the salt or brine solution, osmotic action begins. This continues until the state of equilibrium is established between the brine and the juice of the vegetable. Because of osmotic action, juice is drawn from the vegetable into the brine and brine is taken up by the vegetable. At the start the flow of juice outward is more rapid than the inflow of brine. This causes a slight shriveling of the vegetable. Later the inflow is sufficiently rapid to cause the vegetable to become firm and plump again.

References
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Color in Foods--Chlorophyll

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Color in Foods --- Chlorophyll

The color of fruits and vegetables is exceedingly important to our eating pleasure. "We eat with our eyes" someone has said, meaning that food must look good if we are to eat it. And color more than anything else makes food look good, whether on the dining table or at the supermarket.

The universal coloring matter in plants — the green color which we prize in peas, beans and leafy vegetables—is a green pigment known as chlorophyll. Whether green vegetables keep their garden fresh color until they reach the table depends upon what happens to the chlorophyll in them.

Retaining this garden green color in vegetables is important to the homemaker who wants her family to eat them, and to the processor who wants to sell them. The smart homemaker and food processor knows how to preserve the chlorophyll in vegetables during cooking and processing. These experiments will enable you to learn some of their "trade secrets".

Experiment No. 1 — Cooking Time and Chlorophyll

A. Purpose: To determine the effect of cooking time on chlorophyll.

B. Equipment and Materials Needed

6 stalks of fresh broccoli, cut in uniform pieces with heads about 1½ inches across

OR 1 small package of frozen broccoli spears

2 saucepans (with lids or foil to cover)

numbered 1 and 2

Measuring spoons

Measuring cups

2 plates of same color, numbered 1 and 2

Slotted spoon or kitchen tongs

C. Procedure

1. If fresh broccoli is used, trim large leaves and tough parts of stems and wash thoroughly. If necessary, soak stalks for ½ hour in salt water (made of 4 teaspoons salt to each gallon of water) to remove insects. Cut broccoli lengthwise into uniform pieces, leaving about 1½ inches across. Refrigerate 1 piece of the fresh broccoli, then separate the remainder into 2 equal portions.

2. If frozen broccoli spears are used, washing, trimming and slicing lengthwise is already done. Simply defrost for 1 hour in the refrigerator so that broccoli may be separated. Refrigerate 1 piece of broccoli, and separate the remainder into equal portions.
3. To each saucepan add 1 cup of water, cover, and bring to a rapid boil.

4. Add broccoli samples to saucepans 1 and 2. Cover and return to rolling boil quickly (takes only 1-2 minutes). Record time and reduce heat under each saucepan to a moderately fast boil. (Not slow).

5. Leave covered and boil saucepan No. 1 for 10 minutes. Lift broccoli spears onto plate No. 1.

6. Leave covered and boil saucepan No. 2 for 30 minutes and observe. Continue boiling for another 30 minutes. If water gets low add more boiling water. When cooking time is up lift broccoli spears onto plate 2.

7. Compare the 2 cooked samples. Also compare each cooked sample with the uncooked.

D. Questions

1. What effect does cooking time have on the chlorophyll in broccoli?

2. What happens to chlorophyll when green vegetables are cooked?

3. Of the samples cooked, which has greater eye appeal? Why?

4. How should green vegetables be cooked to retain all the garden fresh color possible?

E. Conclusions

(From this experiment and the Supplementary Notes in this section write your conclusions in the space provided following the Supplementary Notes)

Conclusions—Experiment 1
Experiment No. 2 — Acid, Alkali and Chlorophyll

A. Purpose: To investigate the effect of acid and alkali on chlorophyll.

B. Equipment and Materials Needed
   1 pound of fresh turnip greens
   OR other green leafy vegetable (about 1 quart of cleaned, trimmed leaves, firmly packed)
   3 saucepans (with lids or foil to cover) numbered 1, 2 and 3
   Measuring spoons
   Measuring cups
   Vinegar
   Baking soda
   3 plates of same color numbered 1, 2 and 3
   1 slotted spoon

C. Procedure
   1. Wash leaves through several changes of water . . . lifting them up and down in each change of water . . . until no sand or grit can be seen or felt in the bottom of the sink. Discard all yellowish, badly injured and older leaves.
   2. Divide leaves into 3 equal portions, and number 1, 2 and 3.
   3. Measure ½ cup of water into each saucepan. Set saucepan No. 1 aside. Add ¼ teaspoon of baking soda to saucepan No. 2, and 1 teaspoon of vinegar to saucepan No. 3.
   4. Cover each saucepan and bring water to a rapid boil. Remove cover and add one sample of vegetable to each saucepan.
   5. Cover each and bring rapidly to a boil. Reduce heat and boil for 10 minutes, leaving cover on.
   6. With a slotted spoon lift each vegetable sample out of cooking water onto the correspondingly numbered plate. Observe color of each.

D. Questions
   1. What effect does baking soda (alkali) have on chlorophyll? Why?
   2. What effect does vinegar (acid) have on chlorophyll? Why?
   3. Which sample would be the most pleasing color for the table? Why?
   4. Why should baking soda not be added to vegetables in cooking or processing?
   5. What causes color changes in cooked and in, processed green vegetables?

E. Conclusions:
   (From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions—Experiment 2
Fruits and vegetables are made up of many types of cells each of which performs a particular function. The figure below is a cross section of a parenchyma cell, the chief type of cell in the edible portion of most fruits and vegetables.

Food Synthesizing Cell of a Green Plant

The material within the cell wall is a viscous fluid or gel called protoplasm. The protoplasm, or living active part of the cell, is represented by the nucleus and cytoplasm. The nucleus directs much of the activity of the cell, such as reproduction, respiration and circulation. The cytoplasm, as a portion of the protoplasm, surrounds the nucleus and forms a rather thin layer inside the cell wall.

Within the cytoplasm are numerous small organized bodies called plastids which make it possible for the cell—which is largely water—to contain substances not soluble in water. The various plastids take their specific name from the pigments they hold, as well as from other functions they perform. Thus, the granular green plastids which hold or contain chlorophyll, the green pigments of vegetables and fruits, are called chloroplasts.

Another important part of the cell is that known as the vacuole. It is a large storage center filled with various materials dissolved in water, such as sugars, salts, and the red and blue pigments called anthocyanins. These are the pigments which give to strawberries, grapes, plums, cherries and other deciduous fruits their brilliant colors.

During cooking, changes occur in the chlorophyll of green vegetables. In raw or uncooked vegetables, chlorophyll is protected from the acid cell sap by its location in the chloroplasts. In studying the properties of chlorophyll during cooking or other processing, some scientists suggest the chloroplasts disintegrate when plant cells are heated and that chlorophyll is released into the cell. Others report that even with cooking chlorophyll appears to remain in the chloroplasts. They find, however, that the chloroplasts shrink, collapse and become lumped in the center of a mass of coagulated protoplasm.

Meanwhile two things may happen to the chlorophyll, since it is so closely associated with the protoplasm: The chlorophyll may be released or at least become more susceptible to chemical reactions than when it is in the raw vegetable; and it is likely that permeability of the membrane surrounding the chloroplasts changes when the cell dies.

At any rate, chlorophyll changes to an olive green color and then to brown, depending upon several factors, such as the acidity of the cooking water and the time and temperature of cooking. Both volatile and nonvolatile acids are released as vegetables are cooked and both may add to the acidity of the cooking medium.

If vegetables are cooked covered, the volatile acids dissolve in the steam which condenses on the lid and drip back into the water, thus increasing acidity. Chlorophyll, which is very sensitive to acid, will then change from a bright green to an olive green. Therefore, green beans, spinach and broccoli cooked in a covered saucepan will be browner in color than if cooked under the same conditions without a cover. When cooked without a cover the volatile acids evaporate, and a more attractive green results. Leaving the cover off during only the early part of the cooking

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1 Reproduced from: The Experimental Study of Foods, Ruth M. Griswold, Houghton Mifflin Company, Boston, Page 162, Figure 6-1.
period also improves the color of cooked green vegetables. “Contrary to somewhat widespread belief, vitamins and minerals do not ‘go off’ in the steam.”

It is possible to neutralize the acidity of the cooking water by adding baking soda (alkali), and thereby, maintain the green color during cooking. Some of the vitamins, particularly vitamin C and thiamine which are very sensitive to heat and alkali, are destroyed. Therefore, baking soda (alkali) should not be added to the cooking water when preparing green vegetables. For best color retention when cooking green vegetables, heat them through as rapidly as possible, then cook for only a short time. They are “done” when cooked to a crisp-tender stage. Fortunately, these practices also help retain the nutrients found in green vegetables.

References
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ADVENTURES IN FOOD SCIENCE

Introduction

A few of the 6000-odd food items you buy in a modern supermarket are fresh. But most of them are processed — cooked, canned, waxed, dried, frozen, bottled, pickled, packaged, wrapped, baked, or changed in one way or another for your convenience. Just pause for a minute and think of all of the prepared mixes, instant foods and beverages, and frozen concentrates at the supermarket!

Yet, many of you feel if you are to buy, cook and eat a variety of these foods, they must look right, taste right and have the right texture. And more and more of you are demanding high nutritive value, too.

The demand for these qualities in the foods you eat holds true whether you cook, can and freeze food produced at home, or buy all of your food at a supermarket. Providing the qualities you demand in food — color, flavor, aroma, texture and nutritive value — is the task of scientists.

Before these processed foods come to the supermarket, scientists probe into their cells and tissues to determine their physical and chemical makeup; to find out the individual components that give them their characteristic color, flavor, aroma and texture; and to find out the kinds of nutrients they provide for us. Then they develop methods of cooking, canning, drying, freezing, storage, packaging and so on to preserve the desirable qualities in food or to change the characteristics you dislike.

Scientists investigate the enzyme, circulatory and respiratory systems of plant and animal cells and tissues to find out changes they undergo — when food is harvested, when it is shipped or stored, when it is cooked, or when it is canned, dried, frozen, or packaged or otherwise processed. They explore ways of controlling deterioration as these processes are applied. Scientists examine the microorganisms and microflora associated with and in food, and explore ways to prevent them from spoiling food.

And the nuclear age brought with it an entirely new field of science — atomic radiation. Scientists are now applying it to canned, packaged and fresh foods to prevent various forms of deterioration and spoilage. Another big new task for food scientists is developing special foods for people to eat on their trips in outer space.

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Color in Foods - Fun With Anthocyanins

Most of the red, purple, and blue colors of fruits and vegetables, flowers and leaves are caused by anthocyanin (an-tho-cy'-an-in) pigments which belong to the chemical family of flavonoids. These pigments have some interesting characteristics which can be demonstrated easily and which are important to know in using fruits and vegetables.

Experiment No. 1 – Acids, Alkalis and Anthocyanins in Fruit

A. Purpose: To determine the effect of acids and alkalis on the anthocyanin color pigment in fruits.

B. Equipment and Materials Needed

2 oz. red fruit juice, such as grape, red raspberry, loganberry or cranberry
Bicarbonate of soda (baking soda) (alkali)
Distilled vinegar (colorless vinegar) (acid)
Water
3 glass custard cups
3 sets of measuring spoons OR 1 set of measuring spoons and large glass of water
3 measuring cups
3 teaspoons for stirring

C. Procedure

1. In one measuring cup with \(\frac{1}{4}\) cup of the vinegar with an equal quantity of water.
2. In another measuring cup dissolve \(\frac{1}{2}\) teaspoon of baking soda in \(\frac{1}{2}\) cup of water.
3. Measure 1 tablespoon of the red fruit juice into each of the 3 custard cups and number them 1, 2 and 3.
4. To cup No. 1 add 1 tablespoon of the vinegar solution and stir. Use different set of measuring spoons for measuring water, vinegar solution and soda solutions OR rinse measuring spoon thoroughly after each use in vinegar or soda solutions.
5. To cup No. 2 add 1 tablespoon of the baking soda solution and stir.

6. To cup No. 3 add 1 tablespoon of water and stir.

7. Compare the three cups and make a note of any differences in color.

8. Add 2 tablespoons of the soda solution to cup No. 1 and stir.

9. Add 2 tablespoons of vinegar to cup No. 2 one at a time and stir. Note color change.

10. Add 2 tablespoons of water to cup No. 3 and stir.

11. Compare the three cups and make a note of the differences in color.

D. Questions
1. What effect does an acid have on the color of the red pigment in fruit juice?

2. What effect does an alkali have on this color? Are these color changes reversible?

3. What would be the effect of the addition of lemon juice to a red fruit punch? Why?

4. How would the addition of carbonated water affect it? Why?

E. Conclusions
(From this experiment and the Supplementary Notes in this section write your conclusions in the space provided following the Supplementary Notes)

Conclusions—Experiment 1
Experiment No. 2 – Acids, Alkalis and Anthocyanins in Vegetables

A. Purpose: To determine the effect of acids and alkalis on the color of anthocyanins in vegetables.

B. Equipment and Materials Needed
   1 small head of red cabbage
   Water
   Kitchen knife
   Cup
   Saucepan
   Hot plate or gas burner
   AND
   All equipment and materials used in Experiment No. 1 except fruit juice

C. Procedure
   1. Chop or shred about ½ head of red cabbage and place in saucepan.
   2. Add 1 cup of water and boil for 10 minutes.

   3. Remove from heat and pour several ounces of the cooking liquid into the cup.
   4. When cool, proceed as in Experiment No. 1 using the cabbage cooking liquid in place of the fruit juice.

D. Questions
   1. What effect does acid have on the color of the anthocyanin in red cabbage? What is the effect of alkali on this pigment?
   2. Are these changes reversible?
   3. Was a variation in the color changes noted? If so, what is the explanation?
   4. How can the natural color of red cabbage best be preserved in cookery?

E. Conclusions
   (From this experiment and the Supplementary Notes in this section write your conclusions in the space provided following the Supplementary Notes).

Conclusions–Experiment 2
Supplementary Notes

Anthocyanin pigments are the red, blue, and violet pigments that occur in some fruits and vegetables. Most of them are soluble in water and sometimes present problems in cooking and processing foods in which they occur. The great variety of colors, hues and tints that are seen in the fruit or vegetable in its natural state, and the changes that take place during processing are due to several factors including the following:

- At a low pH (in presence of acid) these pigments are red or reddish; at high pH's they pass from red through violet to blue.

- The color varies with the amount of pigment present. For instance a concentrated acid solution of an anthocyanin will be definitely red, but will appear blue when more water is added.

- Anthocyanins often occur as mixtures of their various types and this will affect the color. Different varieties of the same fruit or vegetable may have different mixtures of anthocyanins and therefore will react differently with acids and alkalis.

- Yellow pigments called anthoxanthins (an-tho-zan'-thins) and the pigments known as tannins often occur with anthocyanins and affect the color. Red cabbage usually contains anthoxanthin which turns yellow in the presence of an alkali. The yellow then mixes with the blue of the anthocyanin to form a greenish color which is not completely reversed when acid is added to the solution. The red color of peets results from a mixture of several pigments. Often they appear very dark or bluish-red when cooked with skins and roots on, but appear much redder later when peeled and vinegar is added for pickling.

The anthocyanins form salts in the presence of certain metals and the resulting color changes depend upon the particular anthocyanin and the metal ion present. Most of the colors formed are grayish purple. This is particularly important in canning and often in cooking. When tin cans are used for canning fruits and vegetables containing anthocyanins, it is necessary to lacquer the inside of the can. Without this lacquer the metal will cause a discoloration of the fruit.

If a tin plate is used for blueberry pie, the bottom of the crust becomes a grayish blue color. This is especially noticeable if the tin has been scratched so that some of the iron underneath is exposed. If a cherry pie is cut with a steel knife and the knife is allowed to remain in contact with the juice, the change to purple is seen within a short time.

Iron cooking vessels cause a marked change in color and should be avoided in cooking fruit. Long cooking in aluminum vessels, as in making jams and jellies, sometimes causes a slight change in color.

When fruits and vegetables containing anthocyanins are stored for long periods often there is a bleaching of some pigment and a red-brown or brown color develops. If foods are stored in a cool place the change is much slower than when they are stored in a warm room. High temperatures and the presence of oxygen cause more rapid deterioration in color in glass-packed fruits than does the presence of light. Ascorbic acid protects pears, peaches, and plums against color changes and development of off-flavors, but does not protect grape juice.

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(Acts of May 8 and June 30, 1914)
Agricultural Extension Service, University of Florida, and United States Department of Agriculture, Cooperating
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adventures in food science
Color in Foods -- Color Changes in Meats

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Color in Foods -- Color Changes in Meats

When lean beef, such as steak, is freshly cut from the carcass it usually is a purplish red which becomes brighter red after exposure to air for a short time. With some types of packaging it becomes purplish red again, or with long exposure to air it tends to become brownish red.

Cured meat, such as ham, often becomes lighter in color when it has been in the butcher's showcase for a few hours, or when it has been stored under conditions which allow the fat to become rancid.

The following experiments are planned to show how these changes take place and more about what causes them.

Experiment No. 1 -- Oxidation of Lean Beef

A. Purpose: To show the effect of oxygen on lean beef.

B. Equipment and Materials Needed
   1 small slice of freshly cut steak about 1/2 inch thick (uncooked)
   1 square 2" x 2" of a clear impermeable plastic wrapping
   Flat dish

C. Procedure
   1. Place steak on dish.
   2. Press 2 inch square of plastic firmly on flat surface of the slice of steak. Let stand 30 minutes or longer.
   3. Observe for changes in color.

D. Questions
   1. What happens when the plastic is placed firmly on the beef muscle? Why?
   2. What does this mean to the grocer who pre-packages cuts of beef for the customers to select from?

E. Conclusions
   (From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions--Experiment 1
Experiment No. 2 – Effect of Light on Cured Meats

A. Purpose: To show the effect of light on the color of cured muscle meat.

B. Equipment and Materials Needed
   3 small slices of cured ham (uncooked)
   3 small plates

C. Procedure
   1. Place a slice of ham on each plate and number 1, 2 and 3.
   2. Set No. 1 in the refrigerator or a dark closet or cupboard. Place No. 2 in a poorly lighted part of the room. Set No. 3 in direct sunlight if possible.
   3. Compare samples after 30 minutes.

D. Questions
   1. What effect does light have on the color of the ham?
   2. Does the color change make the ham more or less palatable in appearance?
   3. What does this mean to the grocer and to the homemaker regarding storage of ham?

E. Conclusions
   (From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions—Experiment 2

Experiment No. 3 – Peroxides and Color in Cured Meats

A. Purpose: To show the effect of a peroxide on the color of cured muscle meat.

B. Equipment and Materials Needed
   1 small slice of freshly cut cured ham
   Plate
   Small bottle of 4% solution of hydrogen peroxide (can be purchased from drug store at cosmetic counter)
   Glass rod

C. Procedure
   1. Place slice of ham uncovered on plate.
   2. With glass rod apply streaks of hydrogen peroxide to the ham about ¾-inch apart.
   3. Note changes in appearance of ham.

D. Questions
   1. What changes occur in the color of the ham muscle when H₂O₂ is applied?
   2. How is this related to changes that occur when the fat becomes rancid?
   3. What does this mean to the housewife and food market in regard to storing cured meats?

E. Conclusions
   (From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)
Conclusions—Experiment 3

Supplementary Notes

Myoglobin is the pigment which produces most of the pink or red color in muscle meat. Depth of this color depends upon the concentration of the myoglobin. The amount of myoglobin varies with the age of the animal, with the breed, and with the amount the muscle has been exercised.

The color reactions of myoglobin are important in self-service marketing of such meats as steaks, roasts, and chops. These muscle meats are darker in color when first cut but become brighter red after exposure to air. This change is caused by oxygen from the air uniting with the myoglobin to form oxymyoglobin which is bright red in color.

Most consumers choose bright red meats in making their selections from the meat display case in the grocery store. The change from dark red to a brighter red usually takes place within the first 30 minutes after the meat is cut and exposed to air. If the meat is not wrapped and is left exposed to air, within a few hours the muscle will begin to dehydrate on the surface and become darker in color. This change takes place more slowly at a lower temperature than at a high temperature.

As the meat stands in contact with air, the oxymyoglobin is slowly oxidized to metmyoglobin which is brownish in color. The brown color is more rapid if salt is present. Sometimes there is a green discoloration caused by the action of certain bacteria on the muscle pigment. This is not toxic and does not make the meat unfit for eating, but does make it unattractive in appearance.

Several researchers have found that certain kinds of light act as catalysts to color changes in cured meats. This is important in marketing slices of ham and chops in transparent wrappings by supermarkets.

Nearly all high quality beef and pork products have a considerable amount of fat in them. This is desirable because it improves flavor and juiciness of the cooked product; however, the fat can become rancid and cause the meat to have a bad flavor and be unfit for use. This is a problem with long storage of some meats. Rancidity may be caused by several different conditions but the most common ones are: presence of oxygen, presence of light, warm storage temperatures, and the presence of even very small amounts of copper or iron.

When the fat is oxidized to a rancid state it produces peroxide. The peroxide bleaches the red pigment of the muscle in the meat and it becomes a much lighter color. This is most often observed in cured ham which has been improperly stored for several weeks.

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Exploring Leavenings

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Exploring Leavenings

Throughout the country people enjoy quick breads, such as biscuits, muffins, and pancakes. In Florida and other southern states the quick breads are especially popular. If you examine recipes you will note combinations of several different chemicals are used to produce the “gas” in the batter and dough to make the biscuit or muffin light and porous, instead of a hard solid mass.

Our ancestors used baking soda \( \text{(NaHCO}_3 \text{)} \) combined with the acid of sour milk to produce leavening for many baked products. Later they substituted cream of tartar \( \text{(tartaric acid)} \) for the acid of sour milk and made baking powder. Since then much work has been done by food technologists and food processors to develop baking powders that give good results in a variety of storage and baking conditions.

Experiment No. 1 – Action of Baking Soda with Acids

A. Purpose: To compare the volume of carbon dioxide gas produced when baking soda is combined with a neutral substance and with acids.

B. Equipment and Materials Needed

Sodium bicarbonate \( \text{(baking soda)} \)
Potassium tartrate \( \text{(cream of tartar)} \)
\( \frac{3}{4} \) cup plain, whole milk
\( \frac{1}{4} \) cup buttermilk
1 cup water
\( \frac{1}{2} \) cup molasses
4 bottles — all the same size — 12 oz. size is preferable.
4 small balloons — select balloons with strong lip not easily torn.
2 sets measuring spoons
2 measuring cups — with pouring lips
1 teaspoon \( \text{(for stirring)} \)
Small funnel
Spatula or knife with straight edge for use in level measuring.

C. Procedure

1. Using masking tape and pencil, label the bottles 1, 2, 3, and 4.

2. Using a dry funnel, measure 2 teaspoons of cream of tartar into bottle No. 1. Add \( \frac{3}{4} \) cup of water and shake gently until cream of tartar is dissolved.

3. Pour \( \frac{1}{2} \) cup molasses in measuring cup and add \( \frac{1}{4} \) cup of water. Stir with teaspoon until thoroughly mixed and pour into bottle No. 2.

4. Pour \( \frac{3}{4} \) cup of plain milk in bottle No. 3.

5. Pour \( \frac{3}{4} \) cup of buttermilk in bottle No. 4.

6. Using dry funnel, measure 1 level teaspoon of soda into bottle No. 1. Quickly stretch the mouth of a balloon over the mouth of the bottle making sure that no gas can escape. Shake bottle gently for
about half a minute and set it aside. Repeat this procedure for bottles No. 2, 3 and 4, shaking bottles No. 2 and 4 longer to mix the soda with these thicker liquids.

7. Compare the size of balloons after 10 to 15 minutes.

D. Questions
1. Which balloons become the greatest in size? Why

E. Conclusions
(From this experiment and Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions—Experiment 1

Experiment No. 2 – Speed Reaction of Baking Powders

A. Purpose: In this experiment, the speed of reaction of different types of baking powder is compared by mixing the baking powders with water. Albumin is added to the water so that the gas generated will be visible.

B. Equipment and Materials Needed
Several types of baking powder
1 egg white
1 glass measuring cup
2 medium-sized mixing bowls

---

1 strainer
1 piece of cheesecloth or other thin, clean white cloth about 12 x 12 inches
1 fork
Shallow baking pan
Boiling water
1 stop watch, or watch or clock with second hand
1 glass measuring cup for each type of baking powder used
1 glass custard cup for each type of baking powder
1 teaspoon for each type of baking powder
Measuring spoons
Masking tape and felt pen or pencil for labeling

C. Procedure
This experiment is more effective if done by a group. Assign one person to each type of baking powder and one as timekeeper. Part of the group can do Step 2 while others are doing Step 1.

1. Prepare albumin solution as follows: Put egg white in mixing bowl and add 1 cup of water. Stir with fork to break up the white and mix it with the water. Avoid beating or whipping the mixture. Continue stirring until a white precipitate (globulin) appears. Place cheese cloth inside the strainer and strain the egg white mixture through this into the second bowl.

2. Number the baking powders to be used and custard cups and measuring cups to correspond.

3. Measure 1 level teaspoon of each baking powder into its own measuring cup.

4. Measure 1 tablespoon of the albumin solution into each custard cup.

5. At the timekeeper's "go" signal the person assigned to each baking powder pours the albumin from the custard cup over the baking powder in the measuring cup, stirring just enough to moisten the powder. (Extra stirring spoils the experiment.)

6. At the end of every minute for 4 minutes each person makes a record of the highest point of foam for the baking powder assigned to him.

7. At the end of 4 minutes place the cups in a shallow pan of boiling water.

8. Make a record of the highest point of the foam every minute for 4 minutes as in Step 6.

9. Compare the records.

D. Questions
1. Was there a difference in the total height of the albumin at room temperature?
2. Did some baking powders rise faster than others at room temperature?
3. Did some give greater rise when heat was applied than others?
4. Would some baking powders probably be better suited than others for recipes requiring much beating or stirring?
5. Did all baking powders that were labeled "double acting" behave alike?

Caution: Since baking conditions are not used in this experiment it cannot serve to test the overall effectiveness of a baking powder. Therefore, care should be taken to avoid saying that one baking powder is better than another on the basis of this experiment.

E. Conclusions
(From this experiment and the Supplementary Notes in this section write your conclusions in the space provided.)

Conclusions—Experiment 2
Supplementary Notes

Baking powders are composed of sodium bicarbonate (NaHCO₃), plus an acid, salt, and starch. A few contain small amounts of other ingredients such as egg white as a drying agent. The starch is used to help keep the powder from caking and serves to "standardize" the product so that for a given amount of baking powder a certain volume of gas will be produced. This makes it possible to use any one of several baking powders in a recipe.

When the powder is mixed with a batter or dough the soda reacts with the acid to produce carbon dioxide gas (CO₂) which causes the batter to increase in volume and makes a "lighter", more porous product when it is baked or steamed.

The general types of baking powder are tartrate, phosphate, and SAS-phosphate. All are designed to release from 12 percent to 14 percent CO₂, but this gas may be released at different rates during the various stages of mixing and baking.

Tartrate baking powders contain potassium acid tartrate (cream of tartar), KH₂C₄H₄O₆, as well as tartaric acid, C₄H₆O₆, to provide the hydrogen ion which reacts with the sodium bicarbonate. Phosphate baking powders contain either primary calcium phosphate, Ca(H₂PO₄)₂, or disodium pyrophosphate, Na₂H₂P₂O₇.

Both the tartrate and phosphate baking powders are active at the mixing period or early part of baking. These are known as "fast acting" or single acting and care must be taken not to beat the batter too long when using these powders.

SAS-phosphate baking powders contain sodium aluminum sulfate, NaAl(SO₄)₂, as well as phosphate and give a little action during mixing. Principal action occurs during the baking period. This type is known as "double acting".

Although most of the baking powders on the market today are labeled "double acting", they differ in composition and in the proportion of carbon dioxide released during the mixing period and during the early and later stages of baking.

References

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Agricultural Extension Service, University of Florida,
and United States Department of Agriculture, Cooperating
M. O. Watkins, Director
67/5/10M
adventures in food science
Let’s Explore Gels
Prepared by:
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The authors express appreciation to Dr. Helen Cate, Professor and
Head, and Dr. Betty M. Watts, Professor, Food and Nutrition,
Florida State University
A few of the 6000-odd food items you buy in a modern supermarket are fresh. But most of them are processed — cooked, canned, waxed, dried, frozen, bottled, pickled, packaged, wrapped, baked, or changed in one way or another for your convenience. Just pause for a minute and think of all of the prepared mixes, instant foods and beverages, and frozen concentrates at the supermarket!

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Before these processed foods come to the supermarket, scientists probe into their cells and tissues to determine their physical and chemical makeup; to find out the individual components that give them their characteristic color, flavor, aroma and texture; and to find out the kinds of nutrients they provide for us. Then they develop methods of cooking, canning, drying, freezing, storage, packaging and so on to preserve the desirable qualities in food or to change the characteristics you dislike.

Scientists investigate the enzyme, circulatory and respiratory systems of plant and animal cells and tissues to find out changes they undergo — when food is harvested, when it is shipped or stored, when it is cooked, or when it is canned, dried, frozen, or packaged or otherwise processed. They explore ways of controlling deterioration as these processes are applied. Scientists examine the microorganisms and microflora associated with and in food, and explore ways to prevent them from spoiling food.

And the nuclear age brought with it an entirely new field of science — atomic radiation. Scientists are now applying it to canned, packaged and fresh foods to prevent various forms of deterioration and spoilage. Another big new task for food scientists is developing special foods for people to eat on their trips in outer space.

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You can start some food science adventures today that may lead to a career in food science. Over 25 percent of all industries in the United States are related to food, either directly or indirectly. Just think of the career opportunities in such a huge enterprise! This calls for a whole battery of chemists, biochemists, physicists, microbiologists, food technologists, nutritionists, dietitians, engineers and others.

Or if you plan to be an up-to-date homemaker, you can start today to apply the findings of science in preparation and preservation of food. In this way you and your family are assured top quality food on the dining table.

This collection of science experiments will help you improve your cooking, canning and freezing now. These science adventures will help you decide whether you would enjoy a career in food science and technology.

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The Purposes of Adventures in Food Science

- To provide you some experiments which may be used along with 4-H club and other projects.
- To produce some ideas that may be used as demonstrations and exhibits. (Don't forget to make colored photographs of your work.)
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Let's Explore Gels

Gel formation is a very important process in food preparation, both in the home and commercially. In food preparation the stiffening which occurs during meat and flour cookery, the rigidity of pectin and starch gels, the viscosity of many plant juices, the changes that occur in egg cookery and in many other processing operations are a function of the gel. The formation of gels from these products make possible the preparation of a wide variety of foods, such as fruit jellies, gelatin desserts and salads, souffles, puddings, custards, pie fillings and batter and dough products. In this section you will have an opportunity to experiment and find out some things about gels.

Experiment No. 1
A Protein Gel

A. Purpose: To investigate the nature and formation of a protein gel.
To determine the effects of a proteolytic enzyme on the gelation of a protein.

B. Equipment and Materials Needed
- Measuring spoons
- 3 Measuring cups
- 2 Small mixing bowls. Number these 1 and 2.
- 2 Custard cups, cereal bowls or dessert dishes for gelatin mixture.
  Number these 1 and 2.
- Spatula or rubber bowl scraper
- Sauce pan or kettle (for hot water)
- 2 spoons for stirring
- Heavy sharp knife
- 1 Can opener
- Grater
- Gelatin
- Canned pineapple juice, or canned shredded pineapple.
- Frozen or fresh pineapple juice, or shredded or grated fresh pineapple.
- Meat tenderizer (from grocery store)
C. Procedure
1. Measure 1 teaspoon of gelatin into each small mixing bowl.
2. Add 2 tablespoons of cold water to the gelatin in each bowl. Stir. Allow to stand until gelatin is softened. (About 5 minutes).
3. Add ¼ cup of boiling water to each bowl and stir until gelatin dissolves.
4. To bowl No. 1 add ¼ cup of canned pineapple juice or shredded canned pineapple. To bowl No. 2 add ¼ cup of frozen or fresh pineapple juice or shredded or grated fresh pineapple. Stir each gently.
5. Pour contents of bowls No. 1 and 2 into custard cups or dishes of corresponding number. Place in refrigerator. Observe when gel has time to form.

6. After observing, add 1 teaspoon of meat tenderizer to bowl No. 1 and stir in gently. Allow to stand on kitchen counter and observe at 1, 2, and 4 hour intervals.

D. Questions
1. Discuss or explain the sol gel relationship.
2. What is syneresis?
3. How and why does the size of the molecule foster gel formation?
4. How and why does the structure of a protein molecule foster gel formation?
5. Why are gels unique?
6. Why did one sample fail to gel?
7. Explain what happened when meat tenderizer was added to the gel.
8. Why does meat tenderizer tenderize meat? What is the enzyme responsible for this?

Conclusions
(From this experiment and the Supplementary Notes in this section write your conclusions).
Supplementary Notes

proteins are giant molecules. Because of their large size they do not form true solutions. Instead they form sols. In such a dispersed state the gelatin micelles have a strong electrical attraction for the dispersing medium, water. This causes them to become thoroughly hydrated or wetted.

Also figuring in the sol gel formation is the structure of the molecule. A protein molecule is made up of "building blocks" that are linked together in a long chain. The chain is folded or coiled in a fashion to permit its fitting into molecules of varying shapes...spheres, egg and cigar shapes, and fibrous or rod shapes, etc. As the molecule picks up water the chain uncoils or unfolds forming long fibrils.

Multiplied many times as in a sol the unfolded fibrils intermingle and link together to form a three-dimensional network or "brush-heap." As this occurs the water is entrapped in such a way that the viscosity of the system increases...that is, it resists flow. With further activity of this nature, the system "sets" to form a mass called a gel.

Gels are unique in that the dispersion medium is still liquid but is held immobilized by the fibrils forming a definite linked structure. In gelatin, however, these are weak links which break when heated. Such a gel is said to be reversible.

When a proteolytic enzyme reacts with a protein such as gelatin, it attacks the links that hold the amino acids together as a chain. The chain falls apart, a few links at a time, until it is gradually reduced to the amino acids from which it was originally formed. This is what happens when fresh shredded pineapple or pineapple juice is added to gelatin. The chains in the large gelatin molecule are broken down into the original amino acids by the proteolytic enzyme, bromelin. In this state, they cannot form the semirigid network that entraps the water. Canned pineapple or pineapple juice does not cause such a reaction because the heat of canning destroys or inactivates the bromelin.

Enzymes that digest or break down protein are frequently used to tenderize meat. The en-

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1 "A sol consists of a solid phase dispersed in a liquid to yield a mobile, fluid colloidal system...In a colloidal system one substance in a fine state of subdivision is dispersed throughout a second. The first is known as the dispersed phase, the other as the dispersing medium." The Chemistry of Life by Downes, page 52.

2 Micelles (mi'sels): A microscopic particle or unit built up from a number of strongly associated molecules of essentially repeating structure.


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Schematic diagram to show gelling and syneresis

Sol

Chain uncoiling

Gel Network of linked fibrils

Clot and Syneresis Fibrils massing into lump

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An enzyme is one of a class of substances formed in living cells. It speeds up a chemical reaction but does not change during the process. Many enzymes are named or classified according to the substances they cause to react. Thus, one that causes protein to react or split is called protease. An adjective descriptive of the action of the enzyme is made by adding the suffix lytic (meaning to break down) to the root of the word indicative of the substance attacked, hence, the expression proteolytic enzyme. Food: The Yearbook of Agriculture 1859 and Fundamentals of Chemistry by Bogert, pages 467, 470, 479 and 496.
zyme most commonly used for this is papain, which is prepared from the green fruit of the papaya plant. Natives of tropical countries have for many years soaked tough meats or wrapped the meat overnight in papaya leaves before cooking.

The enzyme papain is most active in tenderizing meat at a temperature of 140° F to 176° F . . . that is, it acts most effectively during the cooking period causing a general breakdown of all the structural components of beef muscle. The papain in meat tenderizer likewise breaks down or digests gelatin.

References


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67/5/10M
adventures in food science
Let's Explore Fat Emulsions

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AGRICULTURAL EXTENSION SERVICE
INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES
UNIVERSITY OF FLORIDA
GAINESVILLE, FLORIDA
ADVENTURES IN FOOD SCIENCE

Introduction

A few of the 6000-odd food items you buy in a modern supermarket are fresh. But most of them are processed — cooked, canned, waxed, dried, frozen, bottled, pickled, packaged, wrapped, baked, or changed in one way or another for your convenience. Just pause for a minute and think of all of the prepared mixes, instant foods and beverages, and frozen concentrates at the supermarket!

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Let's Explore Fat Emulsions

The successful structure of many home-prepared as well as commercially manufactured foods depends in a large part on the formation of an emulsion. Foods in which the formation of an emulsion is necessary are: salad dressings, cakes, pastries, cookies, crackers, gravies, sauces, cream soups and pie fillings. Such emulsions are complex systems that offer a real challenge to both the scientist and home-maker. Understanding their chemical and physical nature is necessary to their successful use. In this experiment and the discussion that follows you will discover some things about the formation and behavior of emulsions.

Experiment No. 1
Emulsions and Emulsifiers

A. Purpose: To understand the formation of an emulsion and to investigate the effectiveness of egg yolk as an emulsifier.

B. Equipment and Materials Needed
Measuring spoons
1 liquid or dry measuring cup or small bowl such as a cereal bowl (for use in preparing the solution below)
1 teaspoon or fork for stirring
Solution—Stir together gently 1 tablespoon egg yolk and 1 tablespoon of water
Salad oil
2 two-ounce clear glass bottles with close fitting covers. (Ask druggist to save some for you.) Number these 1 and 2.

C. Procedure
1. Put 2 tablespoons of salad oil in each bottle.
2. Add to each bottle 1 tablespoon of one of the following:
   Water to bottle No. 1
   Egg yolk solution to bottle No. 2
3. Cover each bottle tightly. Shake each vigorously, counting each downward stroke up to 25.
4. Let bottles stand for 10 minutes, then observe. Observe again in 20 minutes and 1 hour.

D. Questions
1. Of the two emulsions prepared, which is more stable? Is egg yolk an efficient emulsifier? Which ingredient is the dispersing phase? Which is the undispersed phase or dispersing medium?
2. Explain the formation of a temporary emulsion.
3. What kinds of forces are usually necessary to form a permanent emulsion?
4. Upon what does the stability or permanence depend? Define a permanent emulsion.
5. Explain how physical forces help in forming a permanent emulsion. What is adsorption?
6. In what two ways do chemical forces operate in forming and stabilizing an emulsion?
7. Explain the adsorbed film and/or interfacial tension theory of emulsification.
8. Explain emulsification in terms of polar and non-polar groups.
9. How and why does an emulsifier operate to stabilize an emulsion?

Conclusions

(From this experiment and the Supplementary Notes in this section write your conclusions).
Supplementary Notes

The stability or permanence of an emulsion depends (1) on how finely the fat droplets are divided and (2) on the presence in the liquid of a substance which can prevent the tiny globules of fat from running together again. An emulsion which can stand undisturbed for long periods of time without the fat droplets running together and separating is known as a permanent emulsion. The substance which gives stability or permanence to such an emulsion is known as an emulsifying agent, an emulsifier, or a stabilizer.

As seen in this experiment, energy in the form of work was necessary to form an emulsion, even a temporary one. In making a permanent emulsion, however, both physical and chemical forces are necessary.

The physical forces consist of such operations as beating, stirring, creaming or shaking. In the home this is often done by hand, but in commercial enterprises motor driven machines are used. Such agitation breaks up the disperse phase into many tiny droplets or particles and thereby greatly increases surface area.

With this vast increase in surface area there appears a peculiar phenomenon or process called adsorption... which is the ability or capacity to attract and hold other substances on a surface. Multiplying the surface area of the disperse phase in turn multiplies its powers of adsorption. Doing this is important in forming a permanent emulsion because it enhances the operation of certain necessary chemical forces.

As suggested above oil and water emulsions are unstable unless a third substance... an emulsifying agent or emulsifier or stabilizer... is added. It is with and through this substance that chemical forces operate (1) to help form the emulsion and (2) to help stabilize it or give it permanence.

Why and how does an emulsifier perform such a two-fold function? The most accepted theory at present is referred to as the adsorbed film and/or interfacial tension theory. According to this theory, the emulsifier is adsorbed more by the interface... of the dispersed phase or dispersing medium (water) than by the disperse phase (oil). This greater concentration at the interface of the undispersed phase or dispersing medium lowers its surface tension... more than that of the dispersed droplets. With lowering of the surface tension the undispersed phase or dispersing medium has less tendency to form drops... and so, more readily flows to form a film around the disperse phase.

Later references are more likely to explain emulsifiers and emulsification in terms of polar (water-loving) and non-polar (water-hating) groups. The molecules of the most stable emulsifiers possess both strong water-loving and water-hating

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1. Introduction to Foods and Nutrition by Stevenson and Miller. Page 129.
2. Fundamentals of Chemistery by Boret, Page 173.

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"When a liquid surface is in contact with that of another liquid the boundary between the two is known as the interface." The Chemistry of Living Cells by Downes, page 22.

"In brief, surface tension is that property of a liquid which causes it to occupy as little space as possible." Chemistry and Cookery by MacLeod, page 195. For a fuller explanation of surface tension see Experimental Cookery by Lowe, Chapter 1 or a good general science or chemistry textbook.
groups. One group, however, must be slightly more dominant in order to create unequal tensions at the surface of the two phases. Otherwise, no emulsion is formed.

If the water-loving part of the molecule is dominant, it is adsorbed more strongly in the water phase than in the oil phase. Thus, it lowers the surface tension of the water phase more than that of the oil phase... and causes the interfacial film of the water phase, although very thin, to develop a concave curvature toward the oil. This tends to draw the oil into a series of minute, spherical droplets... each of which becomes enveloped by a film of the water phase.

As the emulsifier functions in this way to help form the emulsion, it also operates to help stabilize it. And it is here that both the water-loving and the water-hating ends of the molecule come into the picture. As suggested, the water-loving parts of the molecule are attracted to the water phase. On the other hand, the water-hating parts of the molecule have an affinity for the oil phase. Because of this the molecules of emulsifiers arrange themselves on a surface with the water soluble or water-loving end of the molecule in the water phase and the other end in the oil phase. Thus, they act like a coherent film lying between two phases of an emulsion. In this way an emulsifier keeps the tiny globules of oil from touching, running together and rising to the surface... even if the emulsion is left undisturbed for long periods of time.

Of the different substances used as food emulsifiers, egg yolk is outstandingly efficient. In making mayonnaise for instance, egg yolk rates four times as efficient as egg white. Whole egg rates intermediate between these two.

Pectin and certain vegetable gums... gum acacia (gum arabic), carob-bean gum (locust bean gum), gum karaya, gum tragacanth to mention a few... used to stabilize certain types of French dressings are good illustrations of viscous emulsifiers... that is, they are thickening agents. They thicken the water phase making it much more viscous or resistant to flow. In such form, it acts mechanically to hold in the oil droplets and prevents their coalescing (touching and running together).

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