Testing for Lipids, Proteins and Carbohydrates

Author(s): SEP staff (Chemistry of Life lesson)

Lesson Overview

Grade level(s):

Elementary School (K-5), Middle School (6-8), High School (9-12), Grade 5, Grade 6, Grade 7, Grade 8, Grade 9, Grade 10

Subjects(s):

Biology/Life Science, Chemistry

Topic:

Organic molecules: Lipids, proteins and carbohydrates

Big ideas(s):

- There are four classes of biological macromolecules: Proteins, lipids, carbohydrates and nucleic acids
- All biological macro-molecule

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Summary:

Students will test a variety of food samples for the presence of lipids, proteins, simple and complex carbohydrates.

Prerequisites for students:

Students should have learned about the 4 classes of biological (organic) macromolecules and be familiar with basic terminology.

Learning goals/objectives for students:

Students will be able to

- name the four biological macromolecules and their building blocks
- test food samples for the presence of lipids, proteins, and simple and complex sugars

Content background for instructor:

All living things contain organic macromolecules: Lipids, proteins, carbohydrates and nucleic acids. Characteristic for these organic molecules is that they are made up of only a small number of

- **Process of Investigative Science Using Crayfish** (21,313)
- **Perception and the Brain** (27,992)
- **Strawberry DNA extraction** (177,061)
- **Testing for Lipids, Proteins and Carbohydrates** (1,058,378)
- **Sheep Heart Dissection** (40,944)

are made up of a small number of elements: Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus and Sulfur

- Simple tests can detect the presence of proteins, lipids and carbohydrates in given samples (i.e. various food items)

Vocabulary words:

Lipids, fats, sugar, carbohydrates, proteins, macro-molecule, amino acid, glucose, sucrose, monosaccharide, disaccharide, polysaccharide, starch, enzyme, fatty acids, polar/non-polar molecules, nucleic acid, polymer

What you need:

SEP Testing for lipids, proteins and carbohygrates kit which includes all needed testing reagents (K243). If you do not have access to the SEP resource center, you can order the reagents through WARDS or CAROLINA SCIENTIFIC.

Protein station: Biuret reagent, test tubes or clear plastic cups, pipettes, various food items (milk, yogurt, cheese, meat, tofu, apple, potato, yeast, cooked beans, eggs, etc.), plates

Lipid station: Various oils and fats (Olive oil, sesame seed oil, grape seed oil, peanut oil, canola oil,

elements: carbon, hydrogen, oxygen, and to smaller amounts nitrogen, phosphorus and sulfur. They are called "macromolecules" because they are very large, containing long chains of carbon and hydrogen atoms and often consists of repeating smaller molecules bonded together in a repeating pattern (polymers).

Macromolecule	building block
protein	amino acids
carbohydrates	monosaccharides
lipids	glycerol + fatty acids
nucleic acids	nucleotides

1. **Carbohydrates**

Carbohydrates are better known to students as sugars and starches.

Monosaccharides or simple sugars such as glucose and fructose ($C_6H_{12}O_6$) function as energy source in cells during cellular respiration and are also used to build cell structures and other organic molecules within the cells.

Disaccharides are composed of two monosaccharides joined together. Sucrose (table sugar) is a disacharide composed of one glucose and one fructose molecule.

Polysaccharides: Are long chains of monosaccharides bond together. Plants store excess glucose in the form of starch, a polysaccharide composed of long chains of glucose. Starches can be found in potatoes, rice, wheat, corn, bananas, peas, beans, lentils, and other tubers, seeds and fruits of plants. Animals (and humans) store excess glucose in the form of glycogen in the liver and muscles. Between meals the liver breaks down glycogen to glucose and releases it into the blood stream to supply glucose to cells in need. Other important polysaccharides are cellulose and chitin. Cellulose makes up the cell wall of plants whereas chitin provides structure to fungi and the exoskeleton of arthropods.

2. **Lipids**

A lot of lipids function as long-term energy storage. One gram of fat stores more than twice as much energy as one gram of carbohydrates. Lipids are also an important component of the cell membrane. Lipids consist of glycerol and fatty acids "tails". The fatty acid "tails" are long chains of carbon and hydrogen that contribute to the non-polar behavior of fats - they don't mix with (polar) water. The fatty acid chains can be saturated, with all carbons saturated with hydrogen atoms forming a straight chain without double bonds. Unsaturated fatty acids contain double bonds within the carbon chain, which results in a bend of the chain.

walnut oil, margarine, butter, lard, Crisco etc.), milks with various fat content (fat free, 1%, 2% whole milk), solution of egg white, solution of egg yolk, other solutions with and without lipids for Sudan red test, brown paper bags, cotton swabs, Sudan III solution

Carbohydrate station: Various carbohydrates to test (potato, sweet potato, bread, cooked noodles, crackers, corn chips, table sugar, apples, flour, corn starch etc.), Benedict solution, iodine solution, corn syrup, test tubes, hot plate,

Grouping:

Student should be divided up into three groups which rotate between the stations. There, students can work independently or in pairs.
If you don't use stations, students should work in pairs.

Setting:

Classroom or lab. You will need sinks (if you want to students to do the clean up) and electric outlets.

Time needed:

At each station students will need about 30-40 minutes. Additional time at each station could be usefull for students to continue to do follow up investigations (see extensions).

3. **Proteins**

Proteins are complex, specialized molecules composed of carbon, oxygen, hydrogen, nitrogen and sometimes sulfur. The building blocks of proteins are amino acids. There are 20 different amino acids that combine to form polypeptides (proteins). The different amino acids are similar in structure: at the center of the molecule is the alpha carbon that is connected to an amino group, a carboxyl group, a hydrogen atom and the R group (the side chain). The different amino acids have different side chain, but are otherwise identical. Proteins have many important roles in organisms. Structural proteins such as collagen or elastin, provide support. Regulatory proteins such as enzymes control cell processes. Proteins also play an important part in the immune system (antibodies), oxygen transport (hemoglobin), movement (muscles) etc.

4. **Nucleic Acids**

Nucleic acids are composed of building blocks called nucleotides. Each nucleotide is made of a sugar molecule, a phosphate molecule and a nitrogenous base.
In DNA (deoxyribose nucleic acid) the sugar is a deoxyribose and the nitrogenous bases are adenine, guanine, cytosine and thymine. In RNA (ribose nucleic acid) the sugar is a ribose and the bases are adenine, guanine, cytosine and uracil. Nucleic acids carry the genetic information within cells. Nucleic acids won't be explored in this lesson.

Testing for macromolecules

1. **Testing for carbohydrates**

- Testing for the presence of starch (complex sugar)

Lugol's reagent (iodine solution) changes from yellowish-brown to dark purple/black.

- Testing for simple carbohydrates (monosaccharides and some disaccharides)

Benedict's solution is used to test for simple carbohydrates. Benedict's solution is a blue colored liquid that contains copper ions. When Benedict's solution and simple carbohydrates are heated, the solution changes to orange red/ brick red. This reaction is caused by the reducing property of simple carbohydrates. The copper (II) ions in the Benedict's solution are reduced to Copper (I) ions, which causes the color change. Sometimes a brick red solid, copper oxide, precipitates out of the solution and collects at the bottom of the test tube. Complex carbohydrates such as starches DO NOT react positive with the Benedict's test unless they are broken

down through heating or digestion (try chewing crackers and then doing the test). Table sugar (disaccharide) is a non-reducing sugar and does also not react with the iodine or with the Benedict Reagent. Sugar needs to be decomposed into its components glucose and fructose then the glucose test would be positive but the starch test would still be negative.

2. **Testing for lipids**
   - **Grease spot test**/Brown paper test
     As we all know from experience, lipids leave translucent spots (grease spots) on unglazed brown paper bags.
   - **Sudan Red test**
     Sudan red is a fat-soluble dye that stains lipids red. Using Sudan red can show the amount and the location of lipids.
3. **Testing for proteins**
   - **Buiret test**
     Buiret solution is a blue liquid that changes to purple when proteins are present and to pink in the presence of short chains of polypeptides. The copper atom of the biuret solution reacts with the peptide bonds to cause the color change.

Getting ready:

- Gather all materials and set up the stations

Protein station: a.) Put food samples in containers or on plates b.) have beakers or dropper bottles of Biuret reagent ready
Lipid station: a.) Cut small squares of brown paper bag (about 5"x5") b.) have beakers or dropper bottles of Sudan Red out
Carbohydrate station: a.) cook pasta b.) set up hot plates in safe spot c.) have dropper bottles with Iodine solution and Benedict solution ready

The lesson can be set up in a way that students rotate through the stations with an adult facilitating each station. If working in a regular classroom without additional adults, the lesson can be split up so that students do each test on separate days.

Daly Ralston Resource Center:

Food testing kit K243

Lesson Implementation / Outline

Introduction:

The depth of the scientific content discussed with the students will depend on their age and the lesson focus (for ex. nutrition or chemistry)

Ask students what materials their bodies are made out of (Proteins: Hair, fingernails, muscles, tendons, cartilage, enzymes, antibodies, hemoglobin, hormones, etc.), fats (cell membranes, insulating layer around nerve cells, steroids, etc.) and carbohydrates (energy source = blood sugar, stored as glycogen in liver and muscles etc.). Discuss where we get the materials from to build this structures and molecules inside of our bodies (through our food!). Have students brainstorm sources of proteins, carbohydrates and fats in their diet. Tell students that they will test various food items for the presence of

these three macromolecules.

Activity:

In the original lesson students rotated throught the three different stations with an adult facilitating each station. If this is not an option, the three test can be done in separate lessons/days instead of in stations.
Students need to wear safety goggles at all times!!

Protein station

- **Testing for the presence of proteins - Biuret test**
  - Show students the available foods for testing. Ask them which ones they expect to contain protein.
  - Demonstrate to students how to perform the test. Put a food item containing protein into a test tubes (i.e. milk or tofu). If it is not a liquid, add some water and mash it well. Also set up a control, a test tube containing a liquid that does not contain protein (i.e. water). Add about 2ml of Biuret reagent to the test tube. Show students the positive - purple or pink - test result indicating the presence of protein. Discuss the importance of a control.
  - Allow students to test various food items for the presence of proteins (see student handout). Ask students whether they are able to tell which food items contain more protein than others.
  - Be careful: Biuret reagent can stain your skin and fingernails!! (They contain proteins!)

Lipid station

- **Intro**
  - Show students the great variety of lipids. Ask them if they can sort them into different categories.
    - Liquid vs. solid. - Plant derived vs. animal derived.
    Liquid fats (oils) are mostly coming from plant sources. ***For older students provide more detail***: They contain a higher number of unsaturated fatty acids which have "bends" in the fatty acid chain due to double bonds between the carbon atoms. These bends don't allow the fatty acid chains to stack closely and result in the liquid form of these oils. Solid fats are mostly animal derived. They contain a higher number of saturated fatty acids, that have straight fatty acids chains which stack tightly and result in the solid form of these fats. Plant oils can be turned into a solid form (margarine, crisco) by hydrogenating the fatty acids. Hydrogen atoms are added to the fatty acids chain and remove the double bonds that caused the "bends". This process is called hydrogenization.
    -Ask if they see any commonality between the fats and oils derived from plants. - They are all coming from seeds and nuts. Fat is a great source of storage energy. The seeds need sufficient energy to sprout and grow, before they have leaves and can produce more energy through photosynthesis.

- **Testing for the presence of lipids: Sudan red test**
  - Demonstrate how to perform this test and refer to student hand-out. Add 2ml of any oil and 2ml of water to a test tube. Then add 2-5 drops of Sudan red to the mix. Shake. Then repeat with a test tube containing only water. Students will see that Sudan red with stain the fat molecules.
  - Allow students to test different samples for the presence of lipids. Interesting is to test milk with different fat content. The more fat it contains, the more particles the Sudan red will stain.
  - Be careful. Sudan red can stain clothes.
- **Testing for the presence of lipids: Grease spot test**
  - Have students follow the simple directions on their hand-out. Students draw four squares onto their brown paper bag, then use a cotton swab to put samples of three lipids of their choice and water as a control into the squares. Wipe off excess oil/fat and let sit for few minutes to dry. Once dry, the fats will left a translucent spot behind. This can best be seen when you hold the paper up to a light source.
  - Put some sesame or sunflower seeds between two pieces of brown paper and press hard. The seeds are loaded with oil and will leave behind grease spots.

Carbohydrate station

- Test for monosaccharides: Benedict reagent ******This test requires a hot plate and might not be appropriate for lower grades.******
  - Demonstrate how to perform this test.
  - Put 2-3 ml of corn syrup in a test tube
  - Add 1ml of the Benedict Reagent, the solution will look blue
  - Put the tube in a gently boiling water bath. Wait a few minutes.
  - The glucose present in the solution reacts with the copper sulfate in the Benedict reagent and makes copper oxide that is an orange to red-brick precipitate.
    The intensity of the color depends on the concentration of glucose present in the sample.
- Test for Starch (Polysaccharide): Iodine solution
  - Demonstrate how to perform this test.
  - Put 2-3 ml of starch solution in a test tube
  - Add 3-4 drops of iodine
  - A bluish black color indicates a positive test for starch.
- After demonstrating both tests, have students tests various food items for glucose or starch using the above procedure.
  - Students will have to make solutions using distilled water with liquid or powdered samples. If the material is

solid tell students to chop it finely or mush it in a mortar and add distill water before adding the reagent.

Checking for student understanding:

A great way to check whether students have mastered the tests is to give them one or more unknown samples of mixtures of lipids, carbohydrates and proteins and have students perform the tests above to figure out which of the macromolecules the sample contains.

Also roaming the classroom, watching students perform their tests, and asking probing questions also will provide valuable information about their understanding of the subject.

Extensions and Reflections

Extensions and connections:

This lesson can easily tight into a health and nutrition unit. The tests can reveal hidden fats and sugars in food items and the relative amounts of fats, lipids and proteins in food can be determined.

After students have mastered the basic tests, a more open ended, explorative part could follow, where students create their own questions around the macromolecules and foods and design experiments to answer their question.

Students of higher grades can explore a special group of proteins, enzymes, in a lab outlined in the following lesson plan: put link here

Attachment	Size
macromolecules.pdf	123.47 KB

NGSS Topics

Kindergarten through Grade 5:

5. Structure and Properties of Matter

Middle School (6-8) Physical Sciences:

MS. Chemical Reactions

Middle School Life Sciences:

MS. Matter and Energy in Organisms and Ecosystems

High School Life Sciences:

HS. Matter and Energy in Organisms and Ecosystems

NGSS Disciplinary Core Ideas

Grade 5:

5-PS1 Matter and Its Interactions

Middle School (6-8):

MS-PS1 Matter and Its Interactions
MS-PS3 Energy
MS-LS1 From Molecules to Organisms: Structure and Processes

High School (9-12):

HS-LS1 From Molecules to Organisms: Structure and Processes

NGSS Performance Expectations

NGSS Performance Expectations:

5-PS1-1
MS-LS1-7
MS-PS1-2
HS-LS1-6

NGSS Science and Engineering Practices

NGSS Science and Engineering Practices:

Asking Questions and Defining Problems
Planning and Carrying Out Investigations
Analyzing and Interpreting Data
Constructing Explanations and Designing Solutions

NGSS Crosscutting Concepts

NGSS Crosscutting Concepts:

Patterns
Scale, Proportion, and Quantity
Energy and Matter

Standards - Grade 8

Chemistry of Living Systems (Life Sciences):

6. Principles of chemistry underlie the functioning of biological systems. As a basis for understanding this concept:
a. Students know that carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.
b. Students know that living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.
c. Students know that living organisms have many different kinds of molecules, including small ones, such as water and salt, and very large ones, such as carbohydrates, fats, proteins, and DNA.

Standards - Grades 9-12 Biology

Cell Biology:

f. Students know usable energy is captured from sunlight by chloroplasts and is stored through the synthesis of sugar from carbon dioxide.
h. Students know most macromolecules (polysaccharides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.

Standards - Grades 9-12 Chemistry

Organic Chemistry and Biochemistry:

a. Students know large molecules (polymers), such as proteins, nucleic acids, and starch, are formed by repetitive combinations of simple subunits.
b. Students know the bonding characteristics of carbon that result in the formation of a large variety of structures ranging from simple hydrocarbons to complex polymers and biological molecules.
c. Students know amino acids are the building blocks of proteins.

Standards - Grades 9-12 Investigation and Experimentation

Investigation and Experimentation:

a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
d. Formulate explanations by using logic and evidence.
l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

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COMMENTS

This lesson can easily tight

Submitted by qullieyen on August 8, 2013 - 3:23am.

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Funded in part by by the National Center for Research Resources and the Office of Research Infrastructure Programs (ORIP) of the National Institutes of Health through Grant Number R25 OD011097 and by an undergraduate science education award from the **Howard Hughes Medical Institute**

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