The Mystery of Magic Milk

Introduction

Take a pool of milk, add some food coloring, and then drop a bit of soap on it to create an explosion of colors. How does this work? We will try to uncover this colorful mystery! First we will try different types of milk, and water. Then we will replace the food coloring with pepper and try again.

Materials

- Milk: skim, low-fat, whole
- Water
- 8 Plates
- Food coloring (a few colors per group, can share)
- Pepper
- 4 Cups (for holding the liquids before the tests and to make pouring easier)
- A bunch of toothpicks and q-tips (at least 8 of each)
- Another cup to hold some soap
- Masking tape and pen (to label the different tests)

Procedure

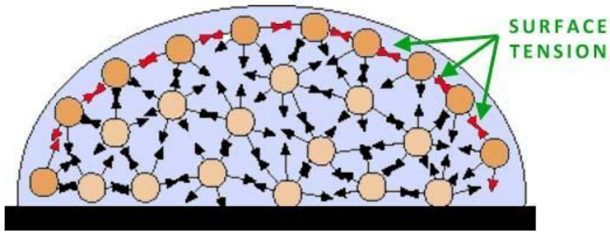
1. Gather up all the materials. Fill up three cups with each type of milk and one cup with water. Make sure you know which cup has which liquid.
2. Set out the 8 plates on the table and place a piece of masking tape in front of each plate. Label the tape with numbers 1-8. (1 = whole/dye, 2 = low-fat/dye, 3 = skim/dye, 4 = water/dye, 5 = whole/pepper, 6 = low-fat/pepper, 7 = skim/pepper, 8 = water/pepper.)
3. Pour each liquid onto its respective plate. Don't pour any pepper or food dye onto the plates just yet. Note: We will first be varying the type of liquid. Therefore, we want to keep consistent other variables, such as dye placement, liquid amount, soap amount, etc.
4. Wait a bit to let the liquids settle.
5. Drop a few drops of food coloring in the center of the whole milk plate (plate 1).
6. Poke the center with a clean toothpick. (Nothing spectacular should happen.)
7. Dip the end of a toothpick in soap. Poke the center of the liquid again. Record on worksheet.
8. Dip a soap-covered q-tip into the same liquid and hold it there. Record your observations. Use the other end of the q-tip to touch another area with soap. Does the magic effect keep happening? Write down on the worksheet how long the effect lasts, how strong it seems, and any other observations.
9. Repeat steps 5-7 with low fat, skim, and water (plates 2-4).
10. Try a similar experiment with pepper instead of the food coloring on both water and milk (plates 5-8). Record your observations.
11. Try discussing some of the questions on the back.
12. Keep exploring! (depending on how much supplies are left)

Questions to think about

- Does it happen with water too? *(It should, but it's not spectacular because the food coloring sinks to the bottom and this is a surface effect.)*
- What does the food coloring have to do with it? *(The food coloring, which is less dense than the milk, floats on the surface. It lets us visualize the effect.)*
- Does the effect happen with pepper instead of food coloring? *(Yes, which leads us to think that it's not the food coloring causing the magic. The food coloring and pepper simply act as indicators of the milk movement.)*
- How does the effect differ between each type of milk? *(I found that it seemed to be strongest and last the longest with the fattier milk.)*
- Why does it differ with each type of milk? *(This is a great question. In science, the answers are not always clear. What do you think? See the "milk fat" section below for some thoughts.)*
- Why does the effect happen in the first place? *Surface tension!*
- Why does it stop eventually? *(An equilibrium is reached in the lowered surface tension.)*

Surface tension

- Milk is mostly water (with some fat and calcium--this extra stuff makes the food coloring, which is pretty much just water, float!) and water has high surface tension.
- *Try this test!* **Use a pipette to add water to a penny, drop by drop. See how high you can make the dome of water without it breaking.**
- Why does this happen? Water molecules want to hold on to each other very tightly. They do not want to separate. Inside the water, each water molecule is pulled in all directions by the surrounding molecules (see picture). However, for water on the surface, there is no water above it to pull upwards. Thus, water on the surface water is pulled inwards tightly. This property is called *surface tension*. If the water molecules didn't care to be next to each other, your water dome would just be a flat puddle. (Note: the is why raindrops are roundish and why the pepper floats on the surface (it should sink after soap is added though!)) This stickiness property of water can be seen very easily. **Drop a bit of water onto the table and gently touch your finger to the surface. Watch as the water grabs onto your finger.**
- *Key fact*: Soap lowers the surface tension of water.
- **Make a mixture of soap and water and then try to see how high you can build a dome on a penny. Compare to the case with plain water.**
- *Explanation of magic milk*: **Let's do demonstration! Hold hands and pull away from each other (gently!). What happens when you are pulling and then let go all of a sudden?** (Note: Be careful!) You feel a force backwards! You are like the water molecules on the milk's surface. Similar to the way you are launched backwards when you let go of each other, the milk shoots outwards when the surface tension is broken by the soap. Another way to visualize it: think about what would happen if you stretched out a rubber hand and then cut the middle.



Milk fat

- The swirling of colors seems to last the longest and be most spectacular with the fattiest milk. Why?
- Many websites explain this experiment by stating that soap attacks fat and so when you add soap to fatty milk, the soap and fat go crazy and their motion causes the milk to swirl around.
- However, we found that it happens with water too, which has no fat! It also doesn't depend on the food coloring, as we showed with the pepper. But it still seems the happen best with the fatty milk.
- The soap is "reacting" with the fat in the milk (forming micelles, etc.). These reactions may somehow contribute to the motion. Or perhaps the fat helps "use up" the soap (through the formation of micelles), so it takes longer for the surface tension to reach equilibrium. What do you think? What experiments could you do to further test the role of fat?

What else is in milk? Proteins!

Proteins are molecules that we need to do lots of the important jobs in our bodies. A protein's shape is very important, as it determines the behavior and function of the protein. Different processes cause proteins to unfold such as heat, change in pH, and change in salinity. When you unfold (or denature) a protein, it can can react with other molecules and precipitate or coagulate. Cheeses (and soybean tofu) are examples of coagulated protein food products.

Precipitation of casein from milk with an acid (vinegar)

Milk protein consists of 80% casein and 20% whey proteins. Milk, in its natural state, is negatively charged. The negative charge allows the dispersion of casein in the milk. When an acid is added to milk, the hydrogen proton concentration neutralizes the negatively charged casein pockets. When milk is acidified to pH 4.7, the casein precipitates.

Materials

- ½ cup warm milk
- 2 teaspoons vinegar
- Stir stick

• 2 plastic cups

• Cheesecloth

• Rubber band

Directions

1. Add ½ cup warm milk to a plastic cup.

2. Add 2 teaspoons of vinegar to the warm milk and stir for 2 minutes, then allow the milk to sit for 5 minutes. The casein will precipitate into heavy white curds.

3. Cut out a piece (2-3 layers) of cheesecloth large enough to cover the top and 2 inches down the sides of a new cup. Using a rubber band, fasten the cheesecloth over the top of the cup. Pour the curdled milk into the cup, collecting the curds (casein) in the cheesecloth and allowing the vinegar and whey to drain off into the bottom of the cup.

4. Gather up the cheesecloth and twist to dry.

5. Have the children record their observations about the cheese. How is the cheese different than the milk it started as? What do the proteins look like now? What did the vinegar do?