Student Worksheet

Ice cream Break with Nanoscience: Nucleation and Colloid Suspensions

Ice cream is a complex food…
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Usually when we enjoy ice cream, we ignore all of the science behind it. Though simple in ingredients, ice cream is actually a complex mixture that consists of solids, liquids, and gases. It's not that we just simply enjoy ice cream, it's that the different phases and ingredients in ice cream come together in a delightful way. Without the right amount of each thing, ice cream wouldn't be as enjoyable. For this activity, we will be making our own ice cream in three different ways and studying our enjoyment of the ice cream as a function of the production method. The first way ice cream will be made for this investigation is using a traditional freezer and a mixture of cream, sugar, and vanilla flavoring, but the production was actually started last night because it takes such a long time for the mixture to freeze. A second way that you'll be doing today is using an ice cream ball maker with a mixture of salt and ice to cool a mixture of cream, ice, and vanilla flavoring. The last way we'll be producing ice cream, and probably the most exciting way, will be with liquid nitrogen! This very cold liquid will be used to cool our cream mixture at such a rapid rate that nano-sized ice crystals form. This method of making ice cream will be compared to both a traditional way of making ice cream in a freezer and with an ice cream ball by "mouthfeel," meaning we get to taste it all!

Nano-sized particles are really, really small particles and we'll be making them today. A nanosized particle is somewhere between 1 x 10-9 and 1 x 10-5 meters. It is the manipulation of matter at the atomic or molecular level that allows such small particles to be formed. There have been countless breakthroughs in a wide variety of industries thanks to nano-sized particles, including medicine, electronics, biomaterials, energy production, optics, and even ice cream making! And while ice cream is something that has been enjoyed since 400 B.C., considerable changes in the manufacturing of ice cream have happened even in the last few years. Traditionally, ice cream was made by freezing a mixture of cream, sugar, and flavoring. While water isn't necessarily an obvious ingredient in this mixture, it does account for 80-90% of milk that the cream is derived from. As such, water comprises a large portion of the cream. So when cooling the mixture to sub-freezing levels to make ice cream, a person is literally making "iced cream," though this is easy to forget when enjoying ice cream today, as it is something so much more than just frozen cream. Upon freezing, water expands, which is easily observed when we freeze water in our freezers: we must always account for the increase in volume by leaving a little space in our vessel due to hydrogen bonding. As freezing of water occurs, the water actually creates small water crystals. The slower the freezing happens, the larger the ice crystals that form. The ice crystals in ice cream can actually be felt quite easily with the mouth and a reduction of ice crystals is desired to give ice cream that creamy "mouthfeel" that so many consumers prefer. To produce smaller crystal sizes for a creamier texture, the rate of freezing must be increased significantly so that the extensive hydrogen bonding by the water molecules is avoided, which is the crystallization. Figure 1 shows how a slower method of freezing (left)

results in many more large ice crystals in an ice cream mixture than a more rapid freezing method (right). The crystal formation in the creamy mixture that is ice cream, results in a colloid solution, a solution where solid particles are equally mixed throughout.
One way to increase the rate of freezing is to provide a lower temperature of freezing. This is not unique to ice cream, rather food products in general. This is one reason many freezer manufactures recommend setting the temperature of your freezer to the lowest possible setting: more rapid freezing results in smaller ice crystals being formed on your food. Many times making homemade ice cream in a personal freezer results in ice cream that is not preferred to commercially available ice cream because the cream mixture is cooled in a regular freezer and it happens very slowly. Homemade recipe directions offer a work around for this problem, which is mixing frequently, but this method can prove to be very tedious and very messy. This procedure was initiated last night.

One method for creating an even lower temperature while mixing the cream mixture is placing the mixture in a container that is completely separated from an outer container that has a mixture of ice and sodium chloride. The salt is added to the ice because it has the ability to lower the freezing point of water, thus lowering the attainable temperature for the ice cream mixture than with just ice itself. This thermodynamic property is known as freezing point depression and it's the reason why salt is spread on some roads in the wintertime. The addition of salt can lower the freezing point of ice by ~20oC with a 1:3 weight ratio of sodium chloride to ice. Subjecting the cream mixture to the ice mixture allows for quick cooling of the cream, however it is still not quite quick enough to prevent ice crystals from forming, albeit they are smaller than the freezer method when the mixture is continuously mixed while freezing. These smaller crystals can still be detected by the mouth of a consumer and provide a kind of "sandy" or "grittiness" to the ice cream.

Another method, which is employed commercially, is using liquid nitrogen to cool the cream mixture. Liquid nitrogen is an extremely cold temperature liquid and boils at -196oC (77 K). In some methods of ice cream production it is used in place of other cooling methods because it causes rapid freezing of anything it comes into contact with and is both colorless and tasteless. This freezing is so rapid, that it prevents hydrogen bonds from forming, resulting in extremely small crystal sizes and an even creamier texture than other methods, which is preferred by most consumers.

1. Question: What affects how creamy ice cream is when we taste it?

2. Question: What are the three methods of ice cream making in this activity?

Materials per group of 2

- Metal mixing bowl
- (2) Styrofoam bowls
- Mixing spoon
- Small ice cream scoop
- Yay Labs Ice Cream Ball
- 50 mL dispensing syringe
- 1 lbs of ice cream salt
- 2-3 lbs of ice
- 1 pint of heavy cream
- 1 pint of half-and-half
- 2/3 cup plus 4 Tbs sugar
- 3 Tbs vanilla extract

Directions for the Activity:

1. Obtain a group number from your instructor. This group number will indicate which salt/ice ratio will be used and how the mixture in the ball will be agitated, so it's important to get it before you begin preparing your activity.
2. First combine ½ pint heavy cream, ½ pint half-and-half, 1/3 cup and 2 tablespoons of sugar, and 1.5 tablespoons vanilla in your metal mixing bowl. Mix thoroughly with spoon.
3. Put your cream mixture into the ice cream compartment of your Ice Cream ball (it's the metal compartment). Tighten the cap with your hand (and not with the plastic wrench).
4. Prepare your ice/salt mixtures by getting appropriate amounts of each according to your group number and the chart below, but do not mix the salt and ice together yet!
5. First put your ice into the outer compartment of the ice cream ball and then add the salt. Some ice chunks may need to be broken up to fit, so crushing the ice first may be helpful. Hand-tighten the cap for this compartment (and again, do not use the plastic wrench).
6. For 10 minutes, agitate the ice cream ball in the way that is assigned by your group number.
7. After 10 minutes, open the ice cream compartment first, you may need to use plastic wrench to do this, then scrape the frozen mixture off of the walls with wooden spoon and mix the cream mixture thoroughly. Replace the cap, again by hand tightening only.
8. The ice compartment is then opened, again you may need to use plastic wrench for this, and replenish the ice and salt in the same ratio as before, then the cap is replaced and hand tighten.

9. Return to agitating the ice cream mixture in the fashion as before, for at least another 30 minutes (more time may be required depending on your ice/salt mixture).
10. Check the freezing of your cream mixture by removing the cap, scraping off the frozen cream mixture and mixing, as before. You want the consistency to be that of soft-serve ice cream. If not, replace cap and continue agitating your ice cream ball.
11. After the ice cream has been made for your group, keep the ice cream in your ball.
12. Make a new mixture by combining ½ pint heavy cream, ½ pint half-and-half, 1/3 cup and 2 tablespoons of sugar, and 1.5 tablespoons vanilla in your metal mixing bowl. Mix well.
13. Obtain a Styrofoam bowl for each member of your group.
14. Your instructor will then fill your bowls with liquid nitrogen. Make sure you do not touch the liquid nitrogen or spill it. Liquid nitrogen will cause immediate frost burns if it comes into contact with your skin!
15. Using a dispensing syringe, suck up your ice cream mixture and dispense into your liquid nitrogen. Stir your mixture immediately, being very careful not to spill the liquid nitrogen. Continue to slowly dispense your cream mixture into liquid nitrogen, making sure each person in your group gets an equal amount. Do so by refilling dispensing syringe and dispensing more until your mixture is gone.
16. Once all of the groups are finished, each group will sample each different type of ice cream by eating 1-2 tablespoons of each of the following: traditional freezer ice cream your instructor prepared ahead of time, your own ice cream made with ball, two other and different group's ice cream made with their ice cream ball, and liquid nitrogen ice cream. You will observe and compare the different mouth feels that are experienced. Rank the five different samples of ice cream that you enjoyed from "least creamy," which gets a score of 1, and "most creamy," which gets a score of 5.
17. Enjoy the remaining ice cream your group made from either method. Be sure to share with your partner.

Results:

Group Number	Amount of Salt	Agitation Method
1	¼ cup	Shake only
2	½ cup	Rolling only
3	1 cup	Shaking & Rolling
4	½ cup	Shake only
5	1 cup	Rolling only
6	¼ cup	Shaking & Rolling
7	1 cup	Shake only
8	¼ cup	Rolling only
9	½ cup	Shaking & Rolling

Observations & Analysis: (Example: Ranking of mouthfeel**)**

Ice Cream Production Type	Ranking of Creamiest (1 = least creamy, 5 = most creamy)	Other Observations