LN₂ Ice Cream

**Leading Question:** Why do we stir ice cream while we freeze it?

**Chemical Principles:** States of matter, temperature, temperature scales (Celsius, Kelvin, & Fahrenheit), solutions/mixtures, characteristics of food (taste, smell, mouthfeel, temperature), kitchen/laboratory/chemical safety

**Description:** In this demonstration we will make ice cream by using liquid nitrogen, which rapidly cools the cream mixture. The protocol is adapted from the recipe for cereal milk ice cream, a popular dessert at Milk Bar (Chef Christina Tosi). This dessert will be prepared with liquid nitrogen by using table-side techniques found at modernist cuisine restaurants. Liquid nitrogen is also used to make Dippin’ Dots, which are a quintessential and perhaps the original molecular gastronomy food, made by applying a ‘scientific’ technique to a dessert.

**Background information:**

**States of Matter**

There are four common states of matter: solid, liquid, gas, and plasma. Plasma, however, is not a state of matter you are likely to come across in a kitchen. The state of matter depends on the molecular structure, as well as the temperature and pressure of the system. Temperature is a measure of the average kinetic energy (motion) of the molecules. As the temperature is raised, the average kinetic energy increases, as does the velocity of the molecules. A decrease in temperature will cause the material to convert to a solid and an increase in temperature will favour formation of a gas. Each material will have different phase transition temperatures, which depend on the size of the molecule and how the molecule interacts with neighbouring molecules.

Mixtures of chemicals and large molecules can have complicated combinations of phases. Ice cream is not a true solid, but a semi-solid material known as a colloid. Nevertheless, ice cream is considered to be a frozen cream mixture.
Liquid Nitrogen

Nitrogen is the major component of the air we breathe (78%). Liquid nitrogen (denoted commonly as $\text{N}_2(\text{l})$ or $\text{LN}_2$) is a clear, colourless liquid that is formed by the compression of air followed by the fractional distillation of liquid air. Nitrogen is classified as a cryogenic material because it has a boiling point of -196°C. Nitrogen is considered inert because it does not readily react, a property that comes from the very strong nitrogen-nitrogen triple bond.

Safety Concerns

Working with liquid nitrogen raises several safety concerns. Firstly, $\text{LN}_2$ is a cryogenic fluid and can cause cold burns by rapidly freezing skin. Second, due to the low boiling point of liquid nitrogen, it rapidly evaporates and expands, greatly increasing in volume. This means that liquid nitrogen has an explosive potential if stored in a sealed container. Similarly, ingestion of $\text{LN}_2$ can cause the expansion and rupture of the stomach. Finally, when used in large volumes, $\text{LN}_2$ can displace oxygen, which is required to live, in confined or poorly ventilated spaces. Appropriate personal protective equipment (PPE), including gloves, face masks, closed toed shoes, aprons, and oxygen sensors, and common-sense precautions can be used to mitigate the risks associated with working with liquid nitrogen.

Ice Cream

Is a dairy-based dessert that is usually sweetened with sugar and flavoured with a variety of ingredients. It is a smooth semi-solid foam (contains air pockets). Generally, to be considered ice cream the product should contain at least 10% (w/w) fat, although this is not regulated.
Demonstration Protocol:

Reagents & Equipment

- 4 L Liquid nitrogen
- 2 Stainless steel carafes
- Small spoons, serving cups
- 4 L Half & Half Cream
- 4 cups sugar (confectioners sugar)
- 2 L mixing container
- ½ tsp salt (NaCl)
- Stand mixer
- Spatula
- 2 Types of cereal, 2 cups each
- Mini-ice cream cones (1 per student)

Preparation

24 hrs prior to the demonstration: Prepare 2x → Mix 1 L H/H cream with 4 cups of cereal, incubate O/N at 4°C in the refrigerator. Before class, strain the cereal from the cream and discard the cereal and add 4 cups of sugar, salt and remaining cream.

Notes: I found that Corn Flakes had a stronger flavour than Froot Loops. I would recommend trying out a few cereals next year. I would also suggest adding in sugar and salt until desired taste is met. This exact amount would change depending on the cereal used.

Demonstration

End of Class. Time: 15 minutes

Pour ~300 mL of the cream mixture into a small bowl, add liquid nitrogen until cream mixture is at about -50°C. Measure temperature using an infrared thermometer. Hit this frozen mixture with a spatula to test if the mixture is completely solid. Show the students the hard, brittle ice cream.

Pour about half the cream mixture into a standing mixer and stir on a setting 6. Add liquid nitrogen in ~200 mL aliquots until cream mixture starts coming away from the sides of the mixing bowl. Transfer to a pre-chilled bowl. Prepare the second batch. Serve immediately in cups or small cones.

Notes: Adding liquid nitrogen to a full bowl will cause some spillage. This can be avoided by limiting the total amount of cream to about 1 L per batch and adding liquid nitrogen in small
batches. I found that a good ice cream consistency was reached when the ice cream started coming away from the sides of the bowl. This point comes after ‘stiff peaks’ are formed in the mixture. You need to try out the demo so you know what point is most desired by you.

Discussion Points

Why is the first preparation completely solid, but the second preparation is scoopable? Is ice cream really a solid? What is the lowest temperature you can achieve using liquid nitrogen?

Learning Objectives:

What is molecular gastronomy? – A subdiscipline of food science with a focus on domestic cooking.
States of matter & phase transitions– liquid, gas, solid.
Chemical safety – liquid nitrogen is a hazardous material, but with appropriate PPE, risks can be mitigated.

Images:
https://commons.wikimedia.org/wiki/File:Dippin%27_Dots_Rainbow_Flavored_Ice.jpg

Freezer Burn

Freezer burn can be described as spoilage of food that occurs when it is stored in sub-zero environments. It can occur via two processes in ice cream. First, sublimation of water, the transformation from solid → gas, can occur in freezers. When stored in poorly sealed containers this process can dehydrate ice cream. More important is the second mechanism, the process by which water crystallizes from ice cream. These ice crystals cause a grainy texture. Freezer burn is irreversible (except if the mixture is melted and the ice cream reformed), but the process can be limited by storage solutions and the inclusion of stabilizing ingredients.
Other Notes/Variables/Unanswered questions:

- Eggs can be added to prevent ice crystal formation during storage and preparation. This is commonly done in conventional ice creams to improve mouthfeel. Soy lecithin or corn syrup could also be used.
- Increasing the speed of mixing can increase the air content of the ice cream. This will change the texture of the ice cream.

Additional Demonstration Options/Variations

Rescue freezer burnt ice cream

- Melt ice cream. Use a hand blender if ingredients have broken (separation of fat and water components of ice cream).

Dip n’ Dots

- Add cream mixture dropwise to liquid nitrogen.

Ice cream sand

- Add cream mixture to iSi whipper, charge, dispense into LN$_2$.
- Alternatively, mix on high-speed (KitchenAid mixer) with whisk attachment

Cereal milk ice cream

- (cereal of choice (2L) incubated O/N 4°C in the refrigerator). Variation of Momofuku’s milk bar recipe.

As plain as vanilla

- Label each preparation, Prep A or Prep B. Have someone (secretly!) add either 2 tbsp. vanilla extract or 2 tbsp. vanilla flavouring each preparation, and have them include the identity of each preparation in an envelope.