Luke Collier
Flow Visualization
Spring 2018

Figure 1. Dairy-Free Test Batch, made in a large metal container with a wooden spoon Photo Cred: Jordan Nahabetian

Liquid Nitrogen Ice Cream

A Flow Visualization Report
By Luke Collier

Thanks to our ad-hoc team:

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Introduction

The purpose for this project was to demonstrate the properties of an ultra-cold and inert substance called liquid nitrogen. Its ability to freeze anything instantly makes it unique. Being non-flammable, non-toxic and non-solid makes it relatively safe as well. Yes, relatively safe: it still boils at a hypothermic -196˚C. We used liquid nitrogen to freeze creamy concoctions into a deliciously smooth ice cream. The freezing effect typically happens within a couple minutes; way faster than the traditional ice-and-salt method. The image was only part of this project's results. Since this was ice cream, it had flavor and smell, temperature and sound: It was a full sensory experience. I couldn't eat it on my own, so I proposed to Prof. Hertzberg to provide a demo during the reception on the final day of class. I'm grateful that she could provide the space and cover costs for this project.

Acknowledgements

Critical players to make this happen included Dan Godrick from the ITLL as well as the team at General Air. Mr. Godrick and his team provided the dewar used to store the liquid nitrogen. General Air provided the liquid nitrogen itself. Thank you; this would not have been possible without either part. Thanks to Prof. Jean Hertzberg for allowing me to move forward with this project on my own. Passionate classmates also provided immense help: Jordan Nahabetian helped mix and test a non-dairy variety of ice cream, while fetching ingredients the day of. Zach Marshall offered equipment and helped carry supplies from the car to the lab. Zach Hinck and Gabe McGann carried supplies on the day of the public demonstration. Jake Lanier was a huge help by mixing the ice cream during the demo. Phil and Eric from my Team Epsilon provided ideas and tips as well. I apologize if I missed anybody, but thank you! I want to thank my family for providing much of the equipment and safety gear, as well as the folks at TinkerMill for providing expertise. Lastly, my high school chemistry teacher, Mr. Kloster, did the same demo for my class years ago which provided the inspiration for this project.

Cryogenics: Liquid Nitrogen

Liquid nitrogen is extremely cold and should be used with extreme caution. It is commonly abbreviated as LN2 because N_2 is the diatomic compound of nitrogen. Insulating gloves and goggles are recommended. If making food with it, make sure all of the nitrogen has boiled off before eating it. Be aware of any clothes or dangling objects that the liquid nitrogen could seep into and cause burns. It could seep between gloves and skin which could also cause frostbitten. This liquid is commonly used to kill and remove warts: Don't let this happen to any other part of you! That being said, liquid nitrogen generally doesn't linger when touching an originally room-temperature surface due to the Leidenfrost effect. This effect happens when a liquid touches a surface that is warmer than its boiling point and a layer of insulating gas is formed between the liquid and the surface, causing it to "dance" above the surface[1]. Avoid using plastic when dealing with LN2 unless you want it to shatter. The container that the liquid nitrogen is typically carried in is called a dewar. A dewar is basically a special lab-ready metal thermos that is vacuum-sealed. It has a lid on it that allows minimal flow to the outside air to prevent explosion. That being said, cryogenic fluid can pour out if the dewar is tilted, so make sure it stays upright. Liquid nitrogen can be found at any store that carries cryogenic gas. Welding stores typically carry it too.

Another note on cryogenics: Solid carbon dioxide, better known as dry ice, was considered due to also being non-flammable, but takes a longer time to melt. This is highly unsafe because a frozen chunk of ice cream could have a piece of dry ice that ends up causing damage to the mouth or intestines.

[1] "Latiff Team First 2014" https://vimeo.com/134146637

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Supplies and Ingredients

This recipe was adapted from Steve Spangler Science[2] and the non-dairy was adapted from Minimalist Baker.[3] For 2 quarts of ice cream, 4L of LN2 was more than sufficient to freeze it. The ice cream is rich and creamy because when it is frozen quickly, smaller crystals form. Below are heat transfer calculations to estimate the minimum amount of LN2 needed is 1 to 1.5 liters to achieve a freeze. It's best to overshoot if possible.

	Volume (qt)	Volume (ml) 1qt=946 ml	Density (g/ml)	Mass (g) m	Specific heat (J/gK) c_p	Freezing Point [C] T_2	Room temp [C] T_1	Energy Transfer (J) $Q=m*cp*(T_2-T_1)$
Whole Milk	2	1892	1.033	*1954*	3.35	-1	25	-170231

	Energy Transfer (J)	Boiling Point [C]	Heat of Vaporization[4] (J/mol)	Moles	Molar Mass	Mass (g) m	Density (g/ml)	Volume (ml)
LN2	*170231*	-196	6100	*27.91*	28.0134	*782*	0.807	969

Supplies

1. Large metal mixing bowl
2. Wooden mixing spoons: won't freeze/shatter and insulating
3. Insulating Gloves: Welding or skiing gloves
4. Safety glasses or splash-resistant goggles
5. Tablecloth/plastic sheet or area that can get wet
6. Table or preparation area
7. Many bowls/cones/cups and spoons if serving to a large party
8. Plastic container for storage of ice cream if needed (and a refrigerator / freezer if needed!)

Ingredients

- 1x 4L dewar (source: ITLL)
- 1 to 1.5L of LN2 for every 2 qt (8cup,64oz) ice cream

Non-Dairy ice cream

i. 4x 14oz cans of coconut cream or full-fat coconut milk (Shake before opening!)
ii. 1 cup (8oz) organic cane sugar or sweetener
iii. 2 TBS(1oz) vanilla extract (no vanilla bean)

Dairy vanilla ice cream

i. 1 qt (32 oz) of half and half
ii. 1 pt (16 oz) milk
iii. 3 TBS (1.5oz) vanilla extract
iv. ½ cup (4oz) sugar or sweetener

Other ingredients

a. Ice for storage?
b. Bowls and spoons

Optional Ingredients

c. Chocolate syrup, etc.
d. Cookies (Fun to dip in milk and freeze!)

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[2] https://www.stevespanglerscience.com/lab/experiments/liquid-nitrogen-ice-cream/
[3] https://minimalistbaker.com/vanilla-bean-coconut-ice-cream/
[4] "Nitrogen" *NIST Chemistry WebBook* https://webbook.nist.gov/cgi/cbook.cgi?ID=C7727379&Mask=4

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Directions

Adapted from Steve Spangler Science:

1. In the large steel bowl, add the milk and cream.
2. Add the vanilla and sugar. Stir until the sugar dissolves.
3. At this point, you can add anything you like – get creative.
4. It's time for the liquid nitrogen. Participants put on your safety glasses and gloves. You might want to put the bowl in your sink just in case it overflows (which it probably will) or spread out some plastic on the table. It's impossible to measure how much liquid nitrogen to add, so just pour about a quart (that's equal to about 1 liter) of liquid nitrogen at a time into the bowl. Expect lots of cool fog.
5. Do not stir the mixture… just yet. Let the liquid nitrogen do its job of partially freezing the mixture. If you stir too soon, the concoction will bubble over.
6. Stir the mixture with the wooden spoon. Some of the cream will be completely frozen while other parts will still be liquid. Keep stirring until you have a consistent mixture, and then add more liquid nitrogen.
7. Let it freeze for a few seconds before stirring.
8. Stir, stir, and stir some more until you have a consistent mixture.
9. Keep adding small amounts of liquid nitrogen until you have the perfect creamy consistency.

Appendix

Figure 2:Pouring Liquid Nitrogen