Aerosol Whip Cream Nozzles

Engineering and Optimization of Nozzles for Least Overspray

My Motivation

Every time I use a store bought whipped cream canister, I have to clean up a huge mess. The whip cream is not only on my plate but also everywhere around it. On my recent trip to Germany, I noticed that the whipped cream did not spray out as much. When I took a closer look, I saw that the whip cream dispenser nozzle had a circular dome at the top. The whip cream dispensers I have used in the US are straight, without the spherical shape at the tip. I wanted to investigate if I can design a nozzle shape that would reduce the mess of whip cream outside my plate. I was also curious about the physics behind nozzles and would like to use my research on nozzles to create a unique nozzle that confines the whip cream to a small area.

Whipped Cream Chemistry

Whipped cream consists of air-in-water foam cells surrounded by fat globules stabilized by a protein film.

- Whisking the cream will let air bubbles into the mixture.
- But continuing to whisk, air cells are surrounded by fat globules.
- Fat globules are hydrophobic = do not like water.
- Fat globules then try to get away from the water and will surround air bubbles.
- This structure is held together by proteins from the cream.
- Continued whisking, the fat with air bubbles will form a stable structure. (Cream Science: On Whipping, Butter, and Beyond.)

Canister: 8g N_2O

Molecular Weight=44.013 g/mol

Standard volume of 1 mole of an ideal gas at 1 atmosphere and 0°C is 22.414 liters.

22.414 liter/mol * 8g / 44.013 g/mol = 4.074 liters

Placing into 1 L Bottle gives 4 atmospheric pressure difference (not including the whip cream in canister).

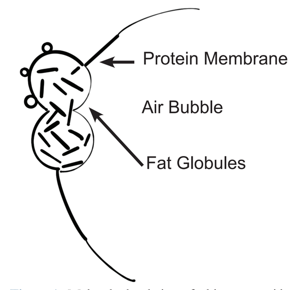


Figure 1: Molecular level view of whip cream with fat globules, air bubbles, and protein membrane.

Canned Whip Cream

- Nitrous Oxide N_2O is used as propellant because it does not react with the whip cream. (Figure 2)
- N_2O is also called laughing gas.
- N_2O stabilizes the cream, resulting in thick whip cream.
- Whip cream chargers: small metal canister that is filled with N_2O. ("Whipped Cream Chargers: Everything You Should Know - Cream Deluxe")

Figure 2: Whip cream dispenser disassembled with N_2O canister is shown.

Research - Nozzle Physics

Flow Resistance

Symbols: R is the flow resistance, Δp is the pressure difference between the two ends, Q is the volumetric flow rate.

$$R = \frac{\Delta p}{Q}$$

Assumptions: Mass conservation

Principle: Flow Resistance R is inversely proportional to Volumetric flow Q at same pressure differential Δp.

Applies to whip cream

Continuity Equation

Symbols: A_1 is the cross-section with velocity v_1 and A_2 is the cross-section with velocity v_2.

$$v_2 = \frac{A_1}{A_2} v_1$$

Assumptions: No density change

Principle: The product of cross-sectional area A and flow velocity v is a constant to preserve mass flow (Ratzlaff, 2020).

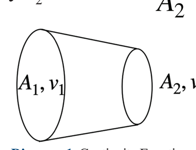


Diagram 1: Continuity Equation explanation with cross section areas and velocities labeled.

Applies to whip cream

Hagen-Poiseuille

Symbols: Δp is the pressure difference between the two ends, is dynamic viscosity, L is the length of the pipe, Q is the volumetric flow rate, and r is the pipe radius.

$$\Delta p = p_2 - p_1 = \frac{8\mu L Q}{\pi r^4}$$

Assumptions: Viscous fluid flow, constant circular cross- section

Principle: When L increases Δp increases.

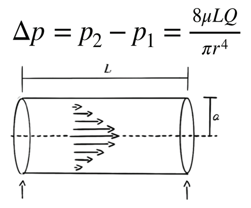


Diagram 2: Liquid moving through a pipe (Tec-Science).

Whip Cream is an Air Liquid Foam

Bernoulli's Principle

$$\underbrace{P_1}_{\text{Pressure Energy}} + \underbrace{\tfrac{1}{2}\rho v_1^2}_{\text{Kinetic Energy per Unit Volume}} + \underbrace{\rho g h_1}_{\text{Potential Energy per unit Volume}} = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g h_2$$

Assumptions: No friction losses, laminar flow

Principle: Conservation of energy

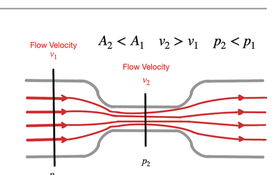


Diagram 3: Venturi Nozzle is displayed with flow velocity v and pressure p.

Whip Cream has Internal Friction

- The whipped cream nozzle problem is the exact opposite of the nozzle design used in aircrafts and rockets where the flow velocity is maximized. ("Nozzle Design | Aircraft Technology")
- Whipped cream is an air-in-liquid foam (Haisman) and is not an ideal fluid and therefore doesn't follow the laminar flow *("What Is Laminar Flow? Computational Fluid Dynamics | SimScale")*.
- Venturi nozzle (Figure 3): in converging section:
  - v increases (Continuity Equation),
  - p lower due to smaller diameter (Bernoulli),
  - additional pressure drop along flow direction due to viscosity of whip cream (Hagen-Poiseuille).
- Reverse Venturi nozzle (Figure 4): in diverging section:
  - v decreases (Continuity Equation),
  - p higher due to larger diameter (Bernoulli),
  - pressure decrease along flow direction due to viscosity of whip cream (Hagen-Poiseuille).

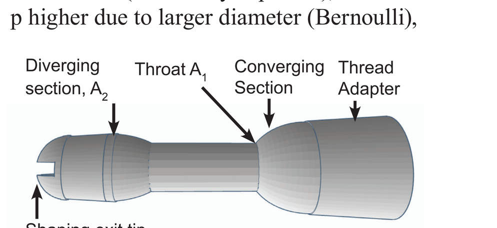


Figure 3: Functional parts of a Venturi nozzle.

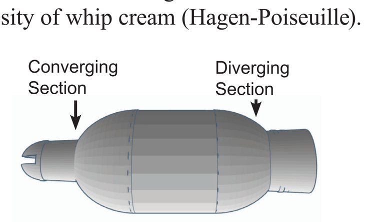


Figure 4: Functional parts of a reverse Venturi nozzle.

Engineering Constraints

Constraints	
Availability	Nozzle materials and printing equipment provided by HeatSync Labs
Cost	Free / donation based
Timeline	It takes half an hour to design a nozzle and an hour to print one.
Manufacturability	Design concept 3D printed
Assembly	Needs to fit on the thread of the whipped cream dispenser.
Quality	The nozzle needs to be leak free.
Reliability	Needs to withstand the pressure of the whipped cream.
Health and Safety	• Material needs to be food grade. PETG filament is considered food safe https://www.wevolver.com/article/food-grade-3d-printing-is-petg-food-safe • Needs to be easy to disassemble and clean
Environmental/Sustainability	PETG is recyclable
User Experience	All nozzle designs were measured to dispense between about 7 g to15 g of whipped cream in the same time.

Table 1: Engineering Constraints for this project are listed above.

References

"Cream Science: On Whipping, Butter, and Beyond." Serious Eats, 2014, www.seriouseats.com/the-science-of-whipped-cream-butter-creme-fraiche. Accessed 26 Feb. 2023.

Douglas Goff, H., et al. "Overview and Fluid Milk Products." Uoguelph.ca, Pressbooks, 2023, books.lib.uoguelph.ca/dairyscienceandtechnologyebook/chapter/overview-and-fluid-milk-products/. Accessed 26 Feb. 2023.

Haisman, D. "IMITATION DAIRY PRODUCTS." Encyclopedia of Dairy Sciences, 2011, pp. 913–916, www.sciencedirect.com/topics/agricultural-and-biological-sciences/whipped-cream, 10.1016/b978-0-12-374407-4.00247-8. Accessed 31 Jan. 2023.

"Khan Academy." Khanacademy.org, 2023, www.khanacademy.org/science/physics/fluids/fluid-dynamics/a/what-is-bernoullis-equation. Accessed 31 Jan. 2023.

"Nozzle Design | Aircraft Technology." K-Makris.gr, 2023, www.k-makris.gr/nozzle-design/. Accessed 31 Jan. 2023.

"Nozzle Design." Nasa.gov, 2021, www.grc.nasa.gov/www/k-12/rocket/nozzle.html. Accessed 31 Jan. 2023.

Ratzlaff, Jerry. "Continuity Equation." Piping-Designer.com, 20 Mar. 2020, www.piping-designer.com/index.php/properties/fluid-mechanics/2780-continuity-equation. Accessed 26 Feb. 2023.

"Tec-Science - Derivation of Hagen-Poiseuille Equation for Pipe Flows with Friction." Tec-Science, 4 Apr. 2020, www.tec-science.com/mechanics/gases-and-liquids/hagen-poiseuille-equation-for-pipe-flows-with-friction/. Accessed 31 Jan. 2023.

"What Is Laminar Flow? Computational Fluid Dynamics | SimScale." SimScale, 26 Jan. 2023, www.simscale.com/docs/simwiki/cfd-computational-fluid-dynamics/what-is-laminar-flow/. Accessed 31 Jan. 2023.

"Whipped Cream Chargers: Everything You Should Know - Cream Deluxe." Cream Deluxe, 23 Aug. 2022, cream-deluxe.com/blog/whipped-cream-chargers-everything-you-should-know/. Accessed 19 Feb. 2023.

* All images, charts, schematics, graphs, tables were created by the presenter. All photos taken by the presenter.

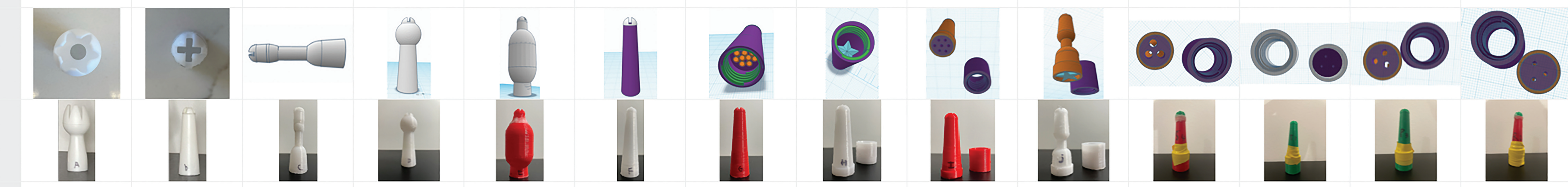
Problem

Whip cream dispensers are known to spray whip cream not only on your dish but also everywhere around. Why is that? Is there a way to avoid spray out and get whip cream just on your cake? Whip cream dispensers contain nitrous oxide N_2O as propellant. The dispenser has a nozzle attached to it to guide the whip cream onto your plate. Is there a way to confine the whip cream to a small area without over spray?

Engineering Goal

The velocity of the exiting whipped cream is controlled by using fluid dynamic principles. For example, applying Bernoulli's equation, one can slow down the whipped cream by widening the direct path opening inside the nozzle ("Nozzle Design") to increase pressure and reduce velocity. The goal of this study is to design a nozzle for a whipped cream dispenser that will minimize the probability of over spray, so that at least 99% of the whip cream is inside an area of 11.2 cm x 15 cm (300 x 400 photo pixels).

Nozzle Prototypes



Prototype Nozzle Name	A	B	C	D	E	F	G	H	i	J	P	R	S	T
Description	Original nozzle supplied with dispenser	Original nozzle supplied with dispenser	Venturi nozzle	Straight with a circular top	Reverse venturi nozzle	Straight nozzle	Straight nozzle with 19 holes at 1 mm diameter each	Straight with a star	Straight nozzle with 7 holes at 1.5 mm diameter each	Venturi with a star	3 holes at 3 mm size	3 holes at 2 mm size	3 holes at 4 mm size	3 holes at 1 mm size
Averaged Overspray ± Error (see Data Overspray Section)	60.1 ± 4.6 %	Not measured since same as F which was 3D printed by presenter for this project.	4.5 ± 14.2 %	11.4 ± 15.3%	0.0 ± 0.0 %	30.0 ±13.0 %	0.1 ± 0.1 %	1.4 ± 0.7 %	0.2 ± 0.2 %	0.2 ± 0.2 %	0.5 ± 0.5 %	0.6 ± 0.6 %	0.3 ± 0.5%	0.6 ± 0.5%

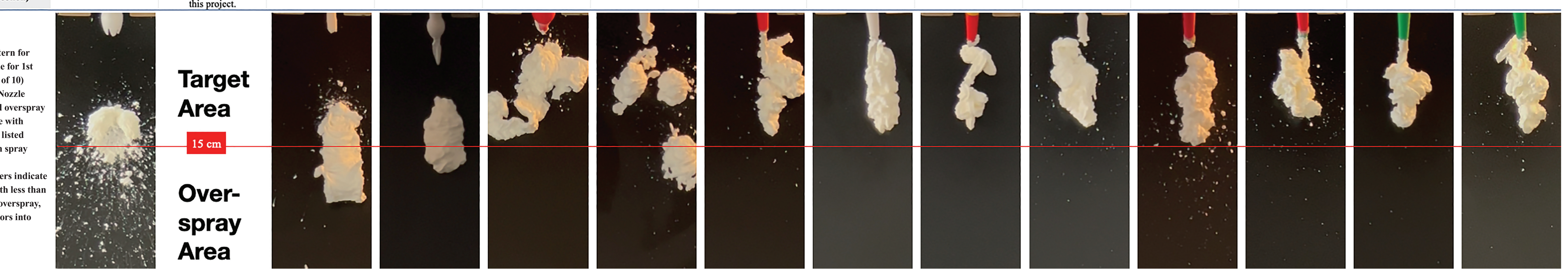
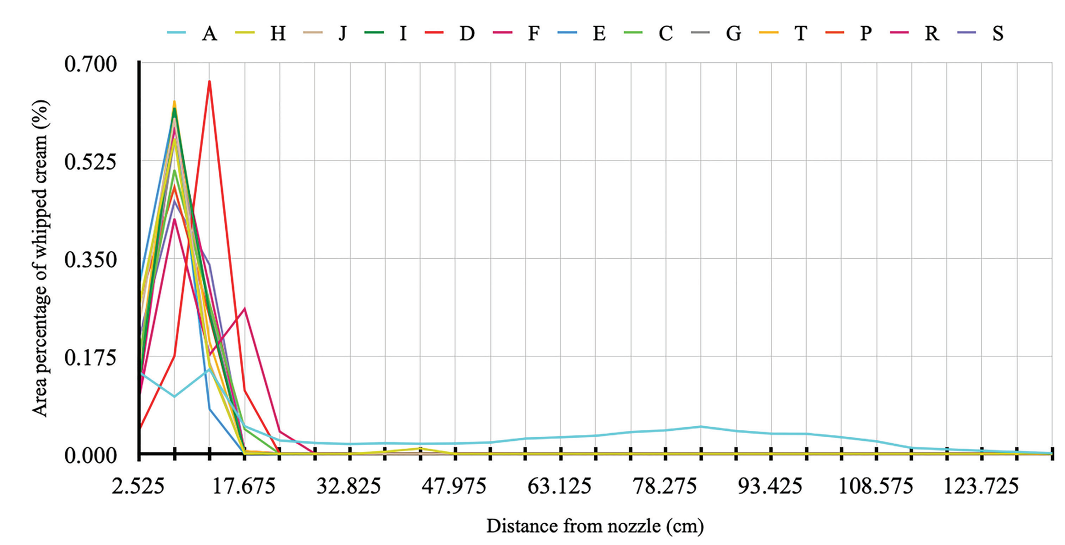


Figure 16: Spray pattern for each nozzle for 1st spray (out of 10) is shown. Nozzle design and overspray percentage with errors are listed above each spray pattern. Green letters indicate nozzles with less than 1 percent overspray, taking errors into account.

Data

• Target area: 0 to 400 pixels (0 to 15 cm) • Overspray area: 401 pixels to 3664 pixels



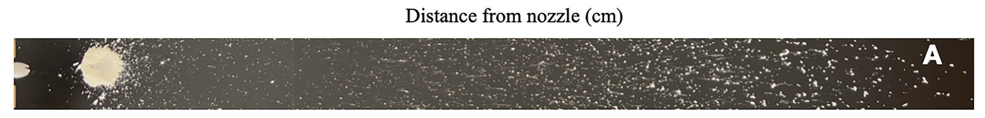


Figure 17: Different Nozzles and their average spray patterns are displayed. Nozzle A actual whip cream spray is shown as example.

Data - Analysis

- The image of the whipped cream spray was imported into the program Image J.
- The target area was selected with the box tool.
- The Image J macro, that was self written, was selected and the macro run.
  - The macro crops the selected area to 300 pixels wide and 3664 pixels long.
  - It then thresholds the image so just the whipped cream is white.
  - After that it makes individual rectangles 300 pixels wide and 150 high until it arrives at the end.
  - It then takes the area percent of white to black within each rectangle.
  - The macro then provides a list result.
- The list results were then copied into a data spreadsheet.
- Then the first 3 numbers were averaged and put into a chart for Target Area.
- The rest of the rectangles were averaged and put into a chart for Overspray Area.
- Then the data was normalized (each rectangle number of white pixels was divided by the total number of white pixels for that run) to be able to compare percent overspray among different runs.

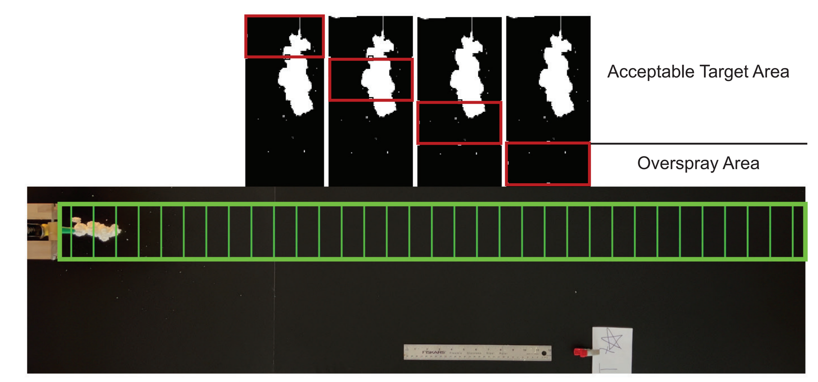


Figure 18: The acceptable target area (first 3 rectangles) and overspray area are highlighted as well as the overall rectangle assignment is displayed.

Data - Overspray

- The worst nozzle is A with over 60% spray outside the target area. Nozzle F (B) was slightly better with 30% and a rather large spread of data with standard deviation of 13%.
- Of all the tested nozzles (Pareto chart, Figure 19), only nozzles E, G, J, I, and S satisfy the 1% overspray limit within error bars. Even though nozzle R, T, P had averages below 1%, the average + error brought them above the goal of less than 1% overspray.
- Nozzles I and J are borderline counting in standard deviations/error.
- Nozzle E had no overspray for all 10 testing runs.

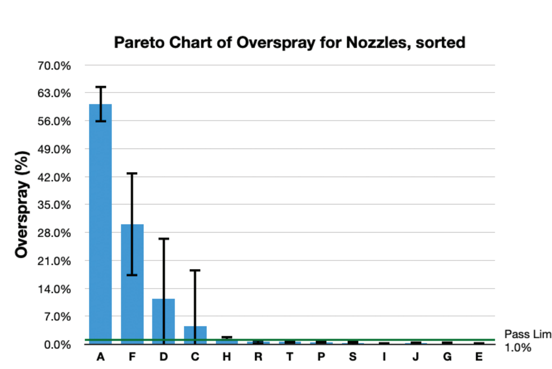


Figure 19: A Pareto chart of overspray for the nozzles, sorted.

Overspray

	Average	Error	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
A	60.1%	4.6%	67.1%	55.3%	58.0%	56.5%	62.0%	61.9%	64.3%	62.5%	53.3%	
C	4.5%	14.2%	44.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
D	11.4%	15.3%	52.9%	10.7%	16.1%	5.9%	10.8%	4.4%	7.9%	3.3%	2.1%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
F	30.0%	13.0%	5.6%	17.0%	22.1%	25.2%	32.8%	36.6%	43.0%	46.9%	42.9%	27.7%
G	0.1%	0.1%	0.1%	0.2%	0.0%	0.0%	0.2%	0.1%	0.1%	0.0%	0.0%	0.1%
H	1.4%	0.7%	1.8%	2.2%	1.9%	2.1%	1.7%	1.1%	1.3%	0.9%	0.6%	0.3%
I	0.2%	0.2%	0.0%	0.3%	0.0%	0.0%	0.1%	0.1%	0.2%	0.0%	0.4%	0.5%
J	0.2%	0.2%	0.6%	0.2%	0.2%	0.2%	0.2%	0.3%	0.2%	0.0%	0.0%	0.1%
P	0.5%	0.5%	1.5%	0.2%	0.3%	0.1%	0.2%	0.4%	0.7%	0.5%	0.3%	1.1%
R	0.6%	0.6%	0.7%	1.1%	1.1%	1.7%	0.3%	0.3%	0.0%	0.0%	0.3%	0.1%
S	0.3%	0.5%	0.1%	0.1%	0.4%	1.5%	0.1%	0.0%	0.1%	0.1%	0.3%	0.1%
T	0.6%	0.5%	1.0%	0.2%	0.2%	0.7%	1.8%	0.2%	0.4%	0.5%	0.3%	0.2%

Table 2: Overspray percentages for each nozzle are shown with their averages and standard deviations.

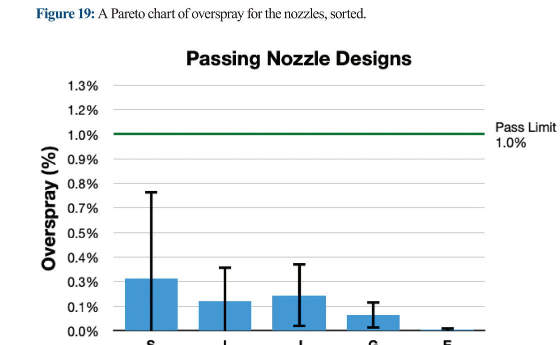


Figure 20: The nozzles that are below 1% overspray are displayed in close up.

Data - Target Area

- Data displayed in Table 3 and Figure 21 show the percent coverage of whip cream within the first 3 rectangles (0 to 15 cm area).
- Ideally a nozzle that passed the overspray test should also have a small area coverage of whip cream in the Target area.
- Nozzle D had whip cream within target area as smallest area. However, this is due to whip cream shooting over the 15 cm target area and resulting in a large overspray and therefore not accounting for all cream inside the target area.
- Nozzle T is second best in Target Area but missed the overspray criteria slightly with 0.6% + 0.5% error.
- Nozzles I and J were within 1% overspray but splattered a lot within the target area.
- Nozzle S has on average 0.3% overspray but has a very clean out spray within target area.
- Nozzle E, with zero overspray, did have a much larger area covered within the target area (22.8%), compared to Nozzle S with only 14.7%.

Target area

	Average	Error	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
A	27.5%	5.3%	26.3%	30.7%	32.2%	28.2%	37.6%	24.2%	23.6%	23.8%	20.6%	
C	19.8%	2.4%	15.9%	23.2%	21.0%	22.9%	20.6%	19.9%	20.3%	18.0%	16.9%	19.2%
D	10.3%	0.8%	9.0%	11.0%	9.9%	10.5%	9.7%	10.9%	11.1%	10.9%	10.7%	9.4%
E	22.8%	6.1%	35.0%	30.1%	28.0%	20.4%	17.3%	17.7%	20.2%	20.6%	19.1%	19.0%
F	24.8%	4.5%	26.6%	24.6%	28.2%	26.6%	31.5%	29.9%	18.6%	22.6%	19.0%	20.5%
G	20.7%	1.6%	21.4%	23.2%	22.9%	20.2%	20.5%	20.6%	19.6%	20.4%	20.0%	17.7%
H	19.4%	1.4%	19.3%	19.7%	21.6%	20.8%	19.7%	17.4%	19.1%	19.5%	17.1%	20.3%
I	20.5%	3.0%	13.7%	21.6%	22.1%	21.4%	24.8%	21.8%	22.1%	20.2%	18.3%	18.8%
J	23.3%	1.5%	22.9%	24.4%	26.2%	22.4%	23.2%	22.4%	23.9%	24.8%	21.7%	21.4%
P	16.8%	0.9%	17.2%	16.1%	16.5%	19.0%	15.6%	16.5%	16.8%	16.9%	17.0%	16.7%
R	16.7%	1.8%	17.4%	18.4%	18.8%	16.6%	17.3%	15.1%	17.6%	14.0%	18.4%	13.8%
S	14.7%	1.7%	15.2%	13.9%	15.5%	14.2%	14.6%	18.1%	12.7%	16.3%	12.8%	13.4%
T	13.2%	1.7%	14.3%	12.0%	14.7%	15.8%	14.3%	13.9%	11.1%	10.5%	12.2%	13.4%

Table 3: Target area percentages for each nozzle are shown with their averages and standard deviations.

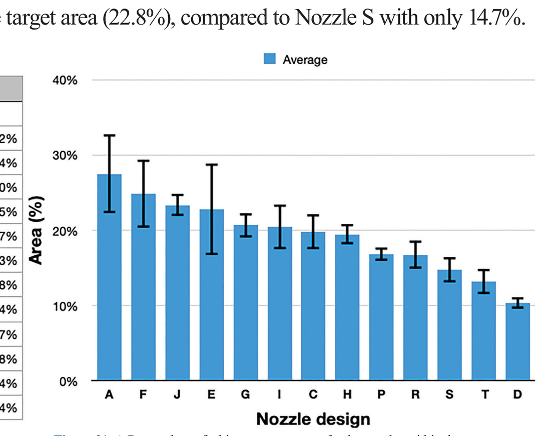


Figure 21: A Pareto chart of whip cream coverage for the nozzles within the target area, sorted

Interpretation

- Most of the nozzles exhibited very repeatable spray patterns. For example, nozzle F consistently had three splotches of whipped cream every time. Figure 22 shows Nozzle S for 3 different runs.
- Nozzle E (Reverse Venturi) had the least overspray at consistent zero percent. The whip cream was slowed down due to narrowing in the nozzle.
- Nozzle S (4mm holes) also passed the overspray criteria. Least whip cream footprint in the target area.
- For the nozzles with holes (P, R, S, T), the diameter of the holes played a role in overspray. Holes with 4 mm diameter worked the best over nozzles with 1, 2, 3 mm diameters.

Error Analysis:

- Nozzle C and D had large errors due to the first spray pattern being partially out of the target zone. The target area for nozzle D was the smallest of all nozzles, the whip cream just went beyond the labeled target area. Nozzle C had zero overspray for run 2 to 10. The nozzles were not cleaned in between runs 1 to 10. Whip cream stuck in the nozzle might have caused Nozzle C to spray inside target area for run 2 to 10.
- Fat particle difference: different whip cream used (due to whip cream shortage) and temperature could affect the fat particles in forming the whipped cream (canister temperature varied due to experimental delays).
- Another error could be how vigorous I shook the bottle after I added the N_2O to the canister. The instructions said to shake the bottle aggressively 5-7 times.

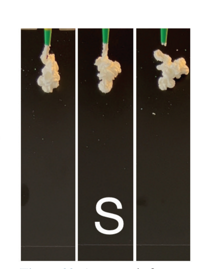


Figure 22: As example for nozzle S, it shows that the set up provided very consistent and repeatable spray patterns.

Conclusion

- Different types of nozzles were designed in Tinkercad and 3D printed then tested for overspray.
- The nozzles that came with the whip cream canister performed poorly. Nozzle A had the most overspray with over 60%. Nozzle B (F) was second in line with 30% overspray. Both nozzles did not have an obstruction embedded.
- The nozzle E, the reverse Venturi nozzle, had no overspray. It did have a target coverage (22.8%) that was larger than nozzle S.
- Nozzle S, three 4mm holes, had 0.3% overspray but a very small target area coverage of 14.7%.
- **The Engineering Goal was Met:** Nozzles S, I, J, G, and E all had less than 1% overspray, taking standard deviation into account. All had either small bore holes, star-shaped obstruction or increased diameter to slow down the whip cream. Reducing velocity, is the most important factor to deliver the whipped cream on target with minimal overspray.
- From a manufacturing point: Nozzle E (7.066 g) is much heavier than Nozzle S (5.425 g). More material = more time to 3D print and more material and production cost.

Future Studies

- Improve the nozzle S design: A whole matrix of hole numbers and sizes could be tested.
- The nozzle E is fascinating as well. It was designed as a reverse Venturi. In the future, I would combining nozzle E and S. Larger cross section also allows to explore larger hole sizes. Also, Hagen-Poiseuille states that pressure drop depends linearly on length L. Could we make the length of the larger diameter section in the reverse Venturi nozzle smaller but keep the same zero overspray?
- I would also be interested in using computer simulations to analyze the nozzles. But in order to do that, I would need to observe the flow since whip cream does not follow Bernoulli or Hagen-Poiseuille principles completely. I could inject a color die with a needle into the whip cream (like the stripes in tooth paste), send this through different transparent nozzles for observation which would then show where turbulences are.

Nozzle Design

1. Measure the existing nozzle dimensions and thread so that the new nozzles fit the dispenser
2. Use Tinkercad to construct nozzles with those dimensions.("Tinkercad | from Mind to Design in Minutes")
   1. The 3D design involves taking a cone, stretching it vertically up and cutting off the tip to make it flat.
   2. Make the cone hollow by placing a hole block inside the cone.
   3. Adjust the hole dimensions for the correct wall thickness of 1 mm.
   4. Similarly, create the tip with a half sphere that is gutted into 4 pieces.
   5. Create the thread with a standard screw thread.
   6. Make variations such as small holes on the bottom. Note: They need to be on the bottom of the print otherwise it would not print correctly without support material.
3. Use PrusaSlicer to slice the 3D design for printing
4. 3D printing:
   1. Printer used was the Ender 5 Pro at Heatsync Labs, Mesa.
   2. Filaments used was PetG (green and white and ABS (red)
   3. Print speed was 100%.
   4. Flow rate was 130% for thicker plastic.
   5. Adding skirt and brim for stability but no raft.

Tip: Some nozzles are designed in two pieces with one part having the threads that fits to the dispenser. This way, one can interchange the top design of the nozzle easily without worrying about the threads. In addition, this method saves 3D printing time and material since the bottom part does not need to be printed again.

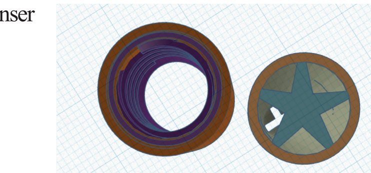


Figure 5: The bottom of a star shaped nozzle.

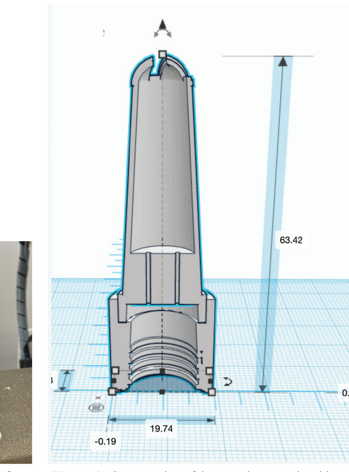


Figure 6: Cross section of the two piece nozzle with internal hole design.

Figure 7: The nozzle during the printing process.

Figure 8: The nozzle after the printing process.

Test Set Up

Test set up is shown in Figure 10. The schematic in Figure 11 shows how the push and pull side of the pneumatic actuator are connected to the control valves (Figure 9, left). An Arduino provides the timing control of the valves. The set point for air pressure was 20 psi.

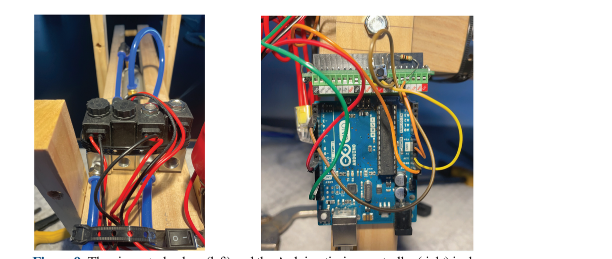


Figure 9: The air control valves (left) and the Arduino timing controller (right) is shown.

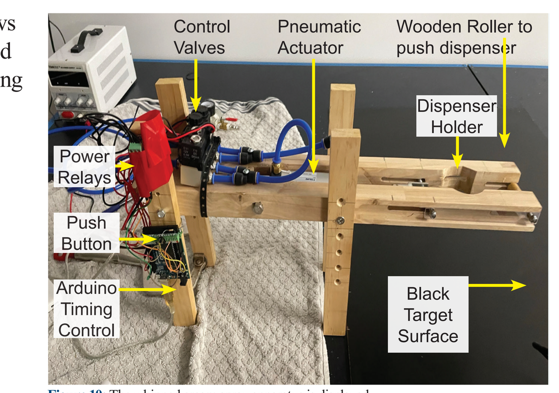


Figure 10: The whipped cream spray apparatus is displayed.

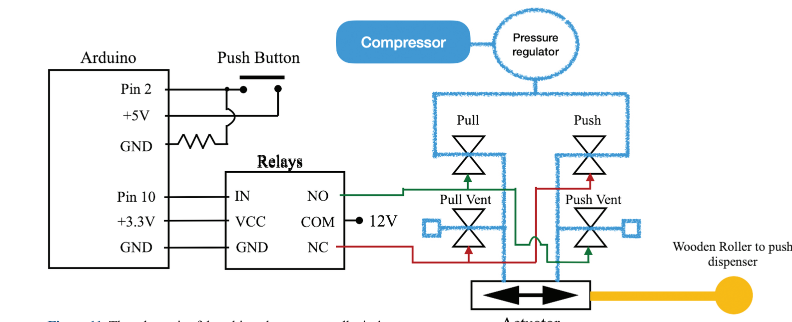


Figure 11: The schematic of the whipped cream controller is drawn.

Testing Procedure

To make sure the whipped cream is sprayed every time the same way and for the same duration, the following test procedure was followed.

Overspray is determined by the amount of whipped cream detected outside the target area which was chosen to be 300 x 400 pixels on camera or 11.2 cm x 15 cm in reality.

- **Independent Variable:** Different Nozzle types
- **Dependent Variable:** Amount of over spray
- **Control:** Nozzle A and B (recreated as F) supplied by manufacturer
- **Constants:** Same angle, same release time, same valve pressure and same height of nozzle above table. Each nozzle started off with fresh N_2O canister.

Figure 12: Whipped cream spray apparatus that shows whip cream bottle with a nozzle and cream being sprayed out.

Whip Cream Nozzle Testing Procedure

1. Store the whipped cream and canister in a refrigerator for 2 hours.
2. Add 2 cups whipping cream into the chilled canister and tighten lid.
3. Tighten the N_2O capsule to the whipped cream lid.
4. Shake aggressively 10 times.
5. Clamp the whip cream canister into the dispensing controller above the blackboard (see Figure 12).
6. Start video recording from above.
7. Turn on power to the dispensing controller (see Figure 13).
8. Press the button to start the Arduino timing program.
9. When program finished turn off power again.
10. Clean the black board.
11. Repeat

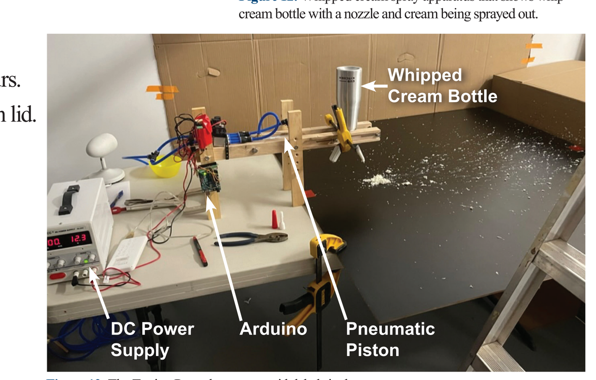


Figure 13: The Testing Procedure set-up with labels is shown.

First Attempt / Problem	Improved Design
Having the pneumatic piston directly push in and out would put too much pressure on the handle.	Improved the design to allow the wooden cylinder to roll to equally apply pressure to the handle.
Only had a valve to let air in and out of pneumatic piston, therefore it would not let go of the handle.	Installed a 2-position 5-way valve to vent and push/pull both sides.
The 2 position 5 way valve only switched under to high pressure.	Installed 2 solenoid valves each for pressurizing and venting push and pull direction of the pneumatic piston. (Figure 14)
The lighting in the garage would create reflections that Image J would mistake for whipped cream even after it was thresholded.	I put the light source on the bottom side of the table to remove the reflections.
The black board was wider than long and some whipped cream was sprayed outside the board. (Figure 15)	To see how far the whipped cream actually went I added another black board and created a T shape because the whipped cream sprayed past the previous black board setup.
With over a hundred videos to analyze I needed a way to find out which video was which nozzle easily.	Every time I used a nozzle I would right down on a paper with the corresponding nozzle and show it on the video.

Table 2: A list of first testing attempts and problems are listed with their respective improved design update.

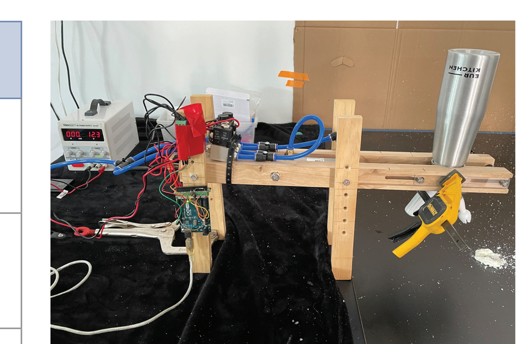


Figure 14: The automatic dispensing controller.

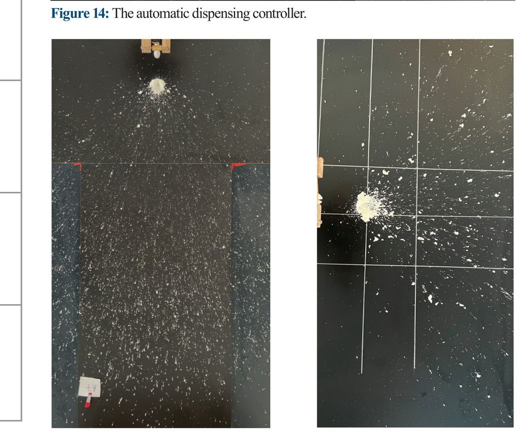


Figure 15: Initial black board (right). T-shaped black boards with label (left)