Easy-Brew Pressure Relief Cap

Produced by Seal of Approval Inc

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Executive Summary

Problem Statement

Fermentation is an easy to use, cost effective process that enhances the nutritional value, and longevity of food, yet the lack of proper equipment presents a challenge to small-scale fermenters. One of the primary challenges in fermentation is the buildup of pressure within the container as a result of the inherent gas production of the process, posing safety hazards, food waste and additional costs. Many of the solutions that exist on the market are relatively expensive, which limits the accessibility to many users. Additionally, many of these solutions are either bulky or cannot be stacked on top of each other because of their design, which limits the possibilities of storage in small kitchens, basements or limited commercial spaces.

Proposed Solution

Seal of Approval inc. is proposing an investment in a different technology that incorporates a spring-loaded mechanism within the lid. The mechanism provides gas relief to the system whenever the inner pressure reaches a dangerous threshold, therefore ensuring a controlled buildup that's necessary for the process. The solution features a side opening for gas relief, to ensure an efficient storage design. The material selection was done along a balanced cost-quality curve to ensure accessibility to the users, and a sustainable margin of profit to the company.

Benefits of the Solution

Our team's solution provides several benefits. First, by integrating an automatic mechanism, our product eliminates the need for manual burping which causes a hazard to the user whenever an unstable jar is manipulated. Secondly, the compact design ensures stickability of fermentation jars making it ideal for users with limited storage space. Thirdly, the design process was made with cost consideration, which allowed our team to offer an affordable product that ensures accessibility to all fermenters, and possibly expand the market, encouraging more individuals to engage in fermentation without the high initial cost. Together, these improvements not only help minimize risk, prevent food waste, and lower costs, but more importantly improve the quality of the overall experience of the users and attract new curious consumers.

Final Thoughts and Next Steps

The target market for our product includes culinary enthusiasts, whether its home fermenters or small-scale food producers who seek to improve the safety, reliability, and affordability of the process. Considering the increasing popularity of commercialized fermented foods like kimchi, kombucha, and sauerkraut, and the rapid market expansion due to the growing awareness of harmful industrial mass food production, more users will be looking for affordable efficient solutions for their home fermentation activities. Additionally, there exists a small business's market that could benefit from our solution, as an affordable and storage efficient alternative.

Abstract and Problem Statement

Fermentation is a time-tested method for preserving and enhancing the nutritional value of various foods. Nowadays, it is used as a large-scale industrial production method, as well as a home food production alternative for individual users. Home fermentation is gaining popularity as consumers become more conscious about food safety, harmful additives, and the benefits of fermentation products to their health. However, traditional fermentation processes pose some challenges, and users look for efficient and affordable solutions to these issues.

Gas production is an inherent result of fermentation and an important condition to the success of the process, but the excessive production of gases causes pressure buildup in fermentation sealed containers. This issue creates some challenges for fermenters associated with the risk of jars breaking, leading to safety hazards from chattered glass, food, and time waste.

This project aims to design an innovative alternative that would address the issues stated above and fulfil the costumer's needs. This report documents the development and design process of a pressure relief lid tailored for standard mason jars, incorporating a spring-loaded mechanism with a protected side gas relief cavity. The fermentation lid keeps the necessary airtight seal all through the fermentation process due to a flexible gasket, while automatically relieving the gas buildup once the pressure reaches a well predefined value that corresponds to the spring rigidity of the mechanism.

Through comprehensive engineering analysis, careful material selection, prototyping and rigorous testing, our team's solution will address the pressure buildup during fermentation with a compact, affordable, and efficient lid that meets the needs of fermentation enthusiasts.

Introduction

Background on Fermentation

Fermentation is an ancient food preservation technique that has allowed humans to preserve the shelf life and enhance the flavor and nutritional value of food. One of the oldest fermentation technologies still used today relies on the biological activity of microorganisms that interact with the food to minimize the growth of undesired microflora. Ancient civilisations as far back as 8000 years ago harnessed fermentation to preserve cheese in Iraq, later the Egyptians using yeast, Sumerians fermenting barley to beer, and the Chinese using fermented mouldy soybean curds as the first manifestation of antibiotics [1]. Today, fermentation is widely used on an industrial scale to produce these effects, utilizing various techniques. But a market of home fermenters is also expanding, due to the growing awareness of food safety, the desire for healthier more natural food options, and the increasing interest in self-sustainability.

Statement of Problem

Fermentation involves the production of gases like carbon dioxide due to the microbial activity. Numerous fermentation processes are done in sealed containers such as glass mason jars, which involves the internal buildup of gaseous by-products of fermentation, leading to hazards of jars unexpectedly breaking, food waste, and safety concerns. An intuitive remedy to this issue is a process called manual burping, where the user would manually relieve the pressure buildup once in a while to limit the risks of dangerous buildup, but this option is not only inconvenient for users, since different fermentation processes may require relief more often than other due to different volumes of gas production, but also poses risks related to the manipulation of high-pressure containers that could crack, and shatter without prior indication, leading to injury. Furthermore, our team's analysis of the current market has proven that existing solutions for pressure relief often lack efficiency, affordability, practicality, compatibility, or all together limiting their appeal to users. Some of the solutions available on the market are bulky which create a storing issue for fermenters, an essential aspect considering their limited storage space. Other solutions are relatively expensive for fermenters managing a small budget for their fermentation activities, limiting access to these gadgets.

Development Approach and Structure

This project will adopt a well-structured development approach that starts with the creation of a strategic plan and a mission statement to guide the design process. The following step involves establishing the need for the fermentation lid by examining market segments, identifying lead users of the product, analyzing the market competitors, examining any legal considerations, and conducting an economic analysis. At the concept development phase, we evaluate the design feasibility and break the design into sub problems, spring, casing, internal lid, to create an initial prototype. The team then proceeds to the detailed design including review and documentation, defining subsystems, identifying suppliers of parts, defining the final geometry for the components, and design tooling for the testing and production. The testing and evaluation phase shifts focus to reliability testing of the lid, regulatory approval, quality assurance, and user training. Finally, to production phase, with an early production assessment and last, a development of a sales plan [2].

Market Analysis and Research

The home fermentation market has expanded significantly over the past decade, fueled by growing interest in health-conscious, homemade food options and the popularity of probiotic-rich foods like kimchi, sauerkraut, and kombucha. This trend aligns with a broader movement toward sustainable living and DIY food preparation, where consumers value both the nutritional benefits and the personalized control they have over their food.

Market Size and Growth

The global market for fermented foods is projected to grow at a compound annual growth rate (CAGR) of 72% from the years 2022 to 2032 [3]. This growth is indicative of increasing consumer awareness about gut health and the advantages of incorporating fermented products into their diet. The associated market for fermentation tools, including jars, lids, and specialty equipment, is also expanding in response to this trend. While precise figures for the fermentation tools segment are not as readily available, it is clear from consumer product launches and online sales growth that the demand for fermentation accessories has increased.

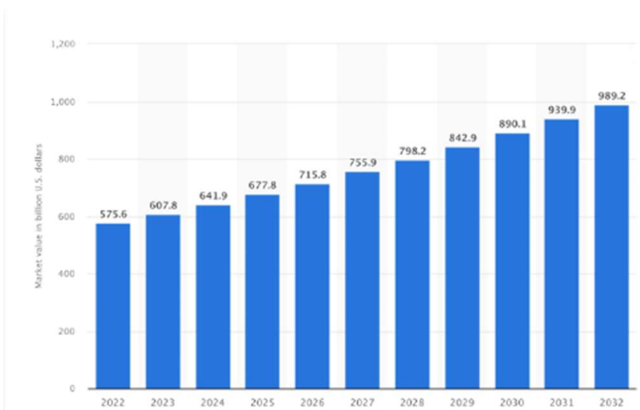

Figure 1: Fermented Food Global Market Size Projection from 2022 to 2032

Consumer Demographics

A study published in pub-med showed that around 29.8% of the 349 subjects interviewed had tried fermenting at home. It showed an increase in at home fermenting activity for those between the ages of 31 – 51 [4].

With increasing popularity resulting from a more health-conscious society, we believe the age range target can be expanded. We believe our primary consumers are:

Young Adults (25-35): Often interested in eco-friendly, sustainable practices, DIY projects, and natural foods.

Middle-Aged Adults (35-55): More likely to have disposable income for kitchen tools and seek ways to enhance family nutrition with homemade fermented foods.

Older Adults (55+): A smaller but notable segment interested in maintaining digestive health and adding probiotic-rich foods to their diet.

Key Competitors

Product	Strength	Weakness
Traditional Lids and Airlock Systems:	Cost-effective solutions that provide basic functionality	Require manual burping to release gas, creating an inconvenience for users.
Electronic Fermentation Lids:	Provide automatic pressure release and precise monitoring	Significantly more expensive and bulkier, making them less accessible for hobbyists or those new to fermenting.
Fermentation Crocks with Water Seals	Effective in maintaining an anaerobic environment	Large, difficult to use and requires frequent maintenance

Table 1: Product Strengths and Weaknesses

Opportunity Identified

Our findings highlighted that while consumers have options for fermentation jar lids, there is an unmet need for a product that offers automatic pressure release at a lower cost and with simpler functionality. Existing competitors either offer basic solutions that require manual intervention or high-end electronic products that are more expensive and less accessible to the average home fermenter. The spring-based pressure release lid is a potentially effective solution combining safety, ease of use, and affordability.

The Real-Win-Worth-It (RWW) framework supported our choice.

Real: There is a demonstrated consumer need for a fermentation lid that handles pressure automatically.

Win: Our team has the technical expertise and manufacturing capability to bring this product to market.

Worth It: The investment is projected to pay off due to the balance of low production costs and potential market reach.

Interviews

Alex: Uses a standard mason jar with a simple plastic lid and ferments about once a month.

Jamie: Utilizes a specialized fermentation crock with a water seal and ferments weekly.

Morgan: Relies on a glass jar with an airlock lid and ferments every few months.

Taylor: A beginner who uses a jar with a regular lid and ferments infrequently

Concerns with their current Lids	
Pressure Build-Up	Multiple interviewees, including Alex and Morgan, noted that pressure build-up led to issues such as leaks, lid popping, and the potential for jars to shatter.
Manual Venting	Jamie mentioned that while their water-sealed crock worked well most of the time, it required attention to ensure the water level was maintained. Alex and Taylor found manually releasing pressure to be a chore.
Clogging and Maintenance	Alex highlighted that built-in valves in automatic lids could become clogged with brine or food particles, requiring frequent cleaning to ensure functionality.
Preferred Features	
Automatic Pressure Release	All interviewees expressed interest in a lid that could release pressure automatically to prevent build-up and potential hazards. Morgan emphasized that this feature was essential for peace of mind, especially with high-pressure ferments.

Ease of Use and Minimal Maintenance	Users like Taylor, who are newer to fermentation, expressed a preference for tools that don't require extensive knowledge or frequent manual intervention.
Safety	Jamie and Morgan highlighted safety concerns related to mold growth and contamination, which could be addressed by ensuring a reliable, airtight seal and pressure release.
Durability	Participants such as Alex and Jamie indicated that they valued long-lasting, food-safe materials like BPA-free plastic or rust-proof metal.
Areas of Product Improvement	
Consistency and Reliability	Some participants reported issues with existing automatic mechanisms being unreliable, with valves occasionally failing to release pressure or wearing out over time.
Affordability	Cost was a recurring theme. Interviewees preferred affordable solutions over more sophisticated, expensive electronic lids, with Alex and Taylor prioritizing lower price points.

Table 2: Customer Interview Results

Our spring-based automatic pressure release fermentation jar lid is designed to fill a clear gap in the market. Through detailed research and consumer interviews, we found that home fermenters face consistent challenges: pressure build-up that can lead to leaks or shattered jars, the hassle of manual venting, and bulky, expensive alternatives that take up too much space.

Our product addresses these issues with a simple, effective solution. The built-in spring mechanism automatically releases pressure to ensure safety and consistency without manual intervention. This makes fermenting easy and stress-free, especially for beginners who want a hands-off experience. Unlike complex and pricey electronic lids, our product is compact, affordable, and built from high-quality, BPA-free materials for long-term use.

Consumers also voiced a need for durable, easy-to-clean equipment. We met this demand with robust, food-safe materials that hold up to repeated use. Our lid's design fits seamlessly into any kitchen setup, providing the functionality of high-end tools without the cost or bulk.

Feedback validated that our product's focus on safety, simplicity, and cost positions it perfectly for both new and experienced fermenters. By bridging the gap between manual lids and high-tech options, our lid offers the best of both worlds a reliable, easy-to-use solution that empowers home fermenters to create confidently

Marketing Strategy

To launch our spring-based automatic pressure release fermentation jar lid effectively, we crafted a marketing strategy that builds awareness, engages consumers, and drives sales. Our plan zeroes in on positioning, promotion, distribution, and pricing, setting our product up for strong market entry and growth.

Our product is positioned as an innovative yet affordable solution for fermentation enthusiasts of all levels. Unlike manual lids that require constant attention or pricey, bulky electronic models, our lid offers safety, simplicity, and convenience. With its automatic pressure release and compact design, it stands out in the market. Our positioning statement sums it up: "Experience safe, easy, and cost-effective fermenting with the automatic pressure release lid that keeps your jars safe and your kitchen tidy."

Our main target audience includes home fermentation fans aged 25-55 who appreciate 'do-it-yourself' food preparation and need reliable, user-friendly tools. This group spans from beginners looking for ease to experienced fermenters wanting time-saving solutions. We also appeal to health-conscious individuals who value natural foods and sustainability but may be new to fermenting.

For promotion, we plan to leverage content marketing, influencer partnerships, and social media campaigns [5]. Educational articles, videos, and step-by-step guides will be shared via blogs, YouTube, and DIY forums to inform potential customers about pressure management and showcase how our product makes fermenting simpler. Collaborating with food bloggers and fermentation experts will build trust through reviews and tutorials. Targeted social media ads will demonstrate the product's key features, boosted by hashtags like #SafeFermentation and #EasyFermenting to enhance visibility. We'll also encourage early adopters to share testimonials, creating word-of-mouth promotion.

Our distribution strategy ensures wide accessibility, starting with major e-commerce sites like Amazon and Etsy, plus a direct-to-consumer website featuring in-depth product details and user support. We'll also explore partnerships with kitchenware and health-focused stores to reach shoppers who prefer buying in person.

Pricing will be competitive, ranging from $4-$7, appealing to budget-conscious buyers and those ready to invest slightly more for safety and ease. This keeps our lid more affordable than electronic competitors while emphasizing its superior function over manual alternatives. Launch promotions will include limited-time discounts and bundle deals with starter kits to attract early buyers and boost product adoption.

Customer engagement is key. Post-purchase surveys will collect feedback to refine future versions and maintain a customer-focused approach. A loyalty program will reward repeat customers with discounts and exclusive content.

With targeted positioning, thoughtful promotion, and a strong focus on customer satisfaction, our marketing plan will ensure our lid becomes an essential tool for home fermenters.

Concept Development

Customer Needs

Our product provides users with a safer alternative to classic mason jar covers. Our lid will be designed to automatically release gas build-up during the process of fermentation. More specifically, it will eliminate the need to manually release these gases. As a result, the chances of jar explosions and food waste will be diminished.

Establishing Target Specifications

Needs to release pressure built up from gases in jar in an automatic way.

Threads of our lid need to conform to the standardized threads of mason jars.

Product needs to be able to disassemble easily for cleaning.

Parts of our lid need to be made from food-safe materials.

The product must be cost-effective.

Concept Generation

Our product will include a redesigned mason jar lid, compression spring(s), and mason jar seal (existing). The mason jar seal will sit on the mason jar per regular configuration. The lid and spring system will screw onto the glass jar and keep the jar airtight. As the gases are produced and accumulated, the gases compress in the jar. As a result, the pressure increases, and the potential energy of the system goes up. As the forces of the pressure push on the seal, the potential energy will convert to kinetic energy and push the seal upwards to release the gas from the jar. The upward movement of the seal will create a force on the spring(s) and compress the spring(s) away from its equilibrium position. Once the gases are released, the spring(s) will move downwards back to its equilibrium position and should close the seal back on the glass jar. The gases will release through holes in the lid. This cycle will be repeated until the fermentation process is complete. The above description is a broad concept idea that still requires prototyping, testing, and refinement and thus is subject to change.

Concept Evaluation

The concept evaluation portion of our product will be evaluated as we produce our prototypes. More specifically, the spring(s) will have to be evaluated extensively. For the system to react the way we plan, we will have to base our spring selection on springs with an appropriate spring constant (k) to withstand the imposed load created by the pressure of the gases in the jar. If k is too high, the force of the pressure may not be strong enough to displace the seal, which ultimately may lead to the jar exploding. If k is too small, the spring may not apply enough force on the seal. This can compromise the seal and cause too much oxygen to enter the jar, thus spoiling the food.

Final Specifications

The final specifications of our product will be determined during the refinement period. This will include spring specifications, dimensions and tolerances of the lid, material selection, manufacturing costs and product lifecycle.

Project Planning

1) Define scope of project: Week of September 16th

2) Write final report: Ongoing as we hit milestones

3) Research (including material selection, manufacturing processes, market opportunities, etc.): Week of September 23rd to week of November 11th

4) Conceptually design product: Week of September 23rd

5) Produce prototype: First prototype: week of September 30th, remaining prototypes to be produced during the month of October

6) Test and refine prototypes: Month of October

7) Manufacture final product: Will start as soon as testing and refinement are completed. Goal: Latest start during week of November 18th

8) Submit final report/introduce to market: December 3rd

Product Development Processes

General (Market Pull) Products: Our market opportunity includes creating a safer version of the mason jar lid, allowing users to ferment without the need to monitor/manually adjust their fermentations.

Platform Products: New lid design for mason jars will be built around current mason jar lid designs. The mason jar band will be replaced by our product, but the sealing lid will still be incorporated. Bands can be placed aside and used once the fermentation process is complete.

Customized Products: Customized version of mason jar lid. The addition of a taller band and spring will be a variation to the current mason jar lid design. Other similar products are currently available, but the goal for our product design is to minimize space usage while creating a more user-friendly and intuitive product.

Quick-Build Products: The modeling of our product is already in development. Our team aims to repeat design and test lid prototype until time runs out. Testing will be time-consuming, requiring enough time for full fermentation cycles to be completed. However, other tests will be incorporated into our test plan to ensure, among other requirements, that the appropriate springs are selected.

Product-Service Systems: Our plan includes a dual-launch, targeting both retail consumers and food service establishments (wholesale outlets). This would allow us to maximize our potential sales and reach.

Product Requirements and Specifications

Technical Specifications

The product is required to fit on a standard mouth mason jar. Figure 26 in Appendix 5 is the engineering drawing for a typical mason jar that was followed to create the necessary dimensions for the lid.

Given the internal pressure will cause rupture of the jar at approximately 12PSI, it is imperative to ensure the pressure remains below this threshold at all times. Factoring in a safety factor of 1.5, we can calculate the max allowable pressure:

$$P_a = \frac{12}{1.5} = 8PSI$$

Using this allowable PSI, an assumption of Δx to off gas is 0.04" and the diameter of the seal of the jar (2"), we can calculate our maximum and minimum spring constants for the selection of a spring.

$$P = \frac{F}{A} \rightarrow P = \frac{K\Delta x}{A} \rightarrow K = \frac{PA}{\Delta x}$$

$$K_{max} = \frac{(8PSI)\pi(1"^2)}{.04"} = 628\,\frac{lbf}{in}$$

$$K_{min} = \frac{(.1PSI)\pi(1"^2)}{.04"} = 7.85\,\frac{lbf}{in}$$

Given the high value found for the maximum, we know we are safe to locate a spring with a k value between 7.85 and approximately 40lbf/in. This enables us to use an off the shelf spring solution without having to create a custom spring at a higher price per unit. The spring selected has a spring constant of 9lbf/in and thus fits the design requirement calculated above. This will ensure the pressure never nears the rupture point, while still maintaining an internal pressure.

Target Specifications

Minimize or Maximize			Technical Specifications (How)										
House Of Quality			Corrosion Resistant of Material	Spring constant (N/m)	Inner Lid Diameter (inch)	Disassembly/Assembly Time (s)	Price per Unit ($)	Food Grade Certification of Material	Overall Dimensions of Unit (inch) (diameter x height)	Threading	Thermal Stability (°C)	Pressure Release Threshold (psi)	
			1	2	3	4	5	6	7	8	9	10	
1	Easy to Clean	3	6	4	2	9	1	1	3	1	6	6	
2	Compact for Storage	2	1	6	6	6	1	1	9	1	1	1	
3	Affordable	2	2	1	1	4	9	6	1	1	1	1	
4	Resistant to Rust	3	9	1	1	6	4	6	1	1	3	1	
5	Long Lasting	2	8	5	1	6	6	6	1	1	6	1	
6	Reliable/ won't fail	4	6	9	8	4	6	4	6	6	9	9	
7	Fits Standard Mason Jars	5	1	5	9	1	1	1	9	9	6	3	
8	Food Safe Usage	4	7	1	1	3	3	9	6	3	9	6	
9	Doesn't Leak	1	6	9	9	7	1	1	6	6	8	9	
													Competitive Assessment
			Silicone	N/A	2.375	0	7.00	Yes	2.375 x 0.25	N/A	-40/200	0.5	Fermentaholics Silicone Stretch Lids [6]
			Rubber and Glass	N/A	2.375	120	2.1	Yes		N/A	-20/70	0.1	Red Hill General Store Airlock Lids [7]
			Silicone	N/A	2.375	N/A	8.4	Yes	2.375 x 0.25	N/A	-40/ 200	2	Masontops Automatic Venting Lids [8]
		Marginal	Strong		2.375	60	15	Yes	5 x 2	63-400	-10/60	0.1	
		Ideal	Rust-proof		2.375	10	5	Yes	3 x 1	63- 400	-40/150	10	
	Importance		46	41	38	46	32	35	42	29	49	37	

Figure 2: House of Quality

Technical Models of Product

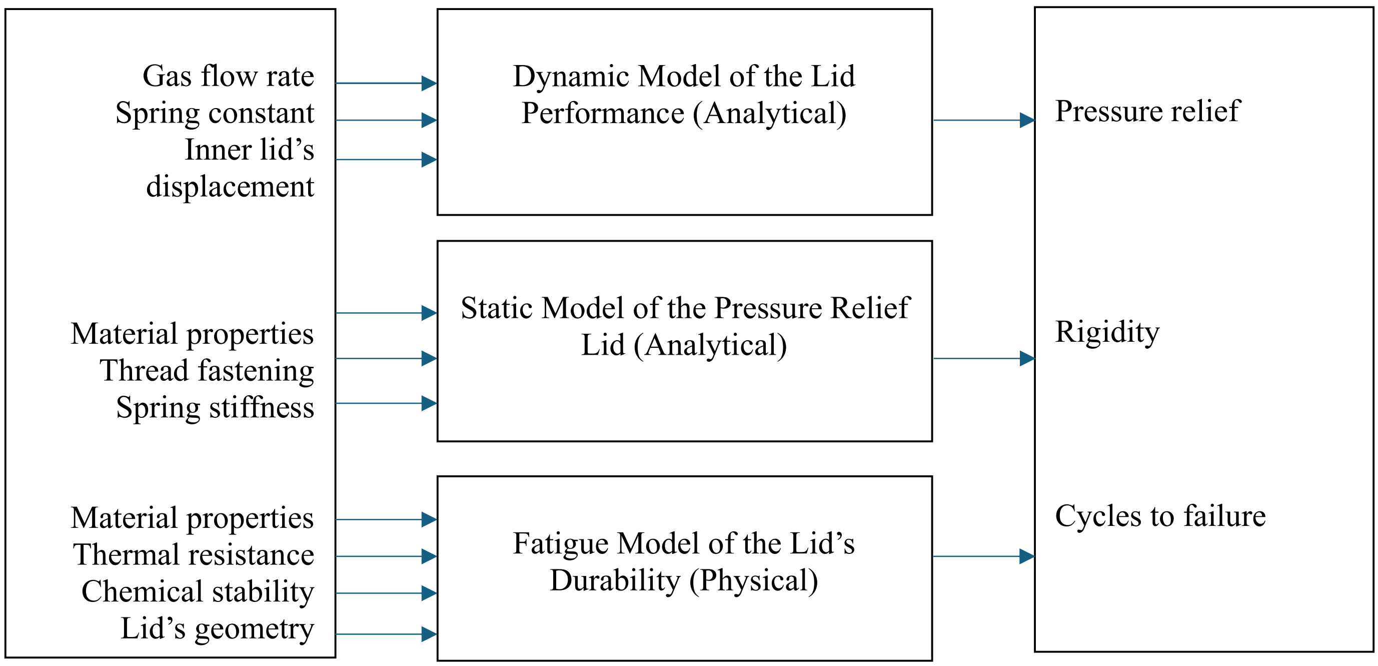

Figure 3: Technical Models

Refined Specifications and Trade-offs

To ensure the product meets market demand vis-a-vis the competition, and to ensure a competitive price, we employed technical and cost models to help us identify areas where we can reduce expenses while maintaining competitive quality. Since the data on the competitive products is limited, we opted to compare performance and price tag based on our results from the cost model and the few published competitor's specifications. Based on these two aspects, our products seem to strike a better quality/cost balance. Our team has seen no need for trade-offs since the product presents a performance advantage by withstanding higher pressure loads, while keeping the production cost lower, which results in lower retail costs compared to the main competitors.

Flow Down of Specifications

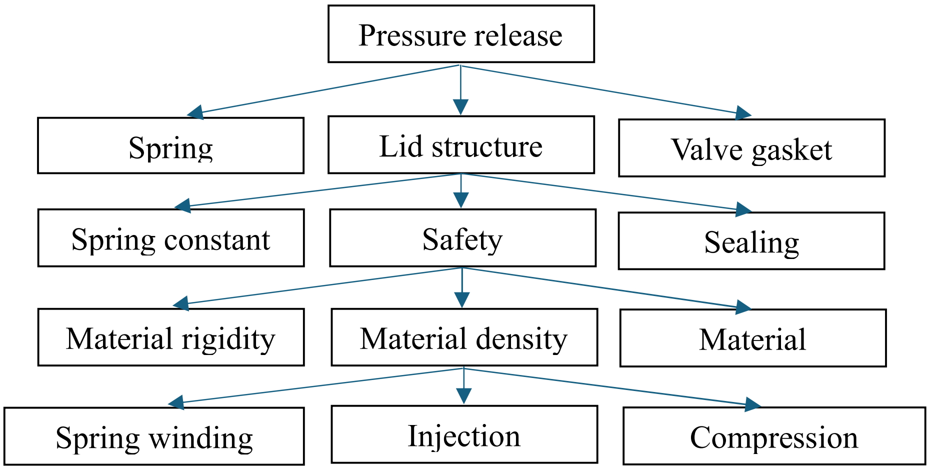

Figure 4: Flow Down Specifications

Final Specifications

	Metric	Units	Value
1	**Corrosion Resistance of Material**	N/A	N/A
2	**Spring constant**	N/m	>
3	**Inner Lid Diameter**	inch	2.375
4	**Disassembly / Assembly Time**	Second	>15
5	**Price per Unit**	$	>5
6	**Food Grade Certification of Material**	N/A	Food safe
7	**Overall Dimensions of Unit (diameter x height)**	inch	3 x 1
8	**Threading**	N/A	63-400
9	**Thermal Stability temperature (T)**	°C	-20 < T < 70
10	**Pressure Release Threshold**	psi	8

Table 3: Final Specifications

Design Process and Prototyping:

The design process utilized the GPI engineering drawing to ensure proper fit of the lid on a standard mason jar mouth. Additive manufacturing was utilized for prototyping, as it allowed for quick turnaround on design changes and functional testing to be conducted on the parts. Due to the low-pressure requirements calculated, the prototypes were able to safely handle the stresses and ensure the proper fit and function of the part, as discussed in the testing section.

Concept Descriptions

V1: The thought process behind the first concept was to create the lid with a similar look to what consumers were used to seeing; this led to a three-piece lid mimicking the traditional outer ring lid with an inner plate. The inner plate was planned to be positioned on top of a spring that compressed the inner sealing lid against the jar. This concept was ultimately abandoned to allow for part reduction by incorporating a solid piece on the outer lid to reduce total part number and increase ease of manufacturing.

V2: With this iteration, the double upper lid was condensed into one piece. Holes were incorporated into the top of the lid to ensure gases were able to freely escape the as the seal broke. A locator for a thin spring was included to allow ease of installation of a spring into the lid prior to consumer assembly of the lid onto a jar.

V3: This version saw a design change of the holes on the top, as well as the method in which the spring was sat into the lid. The let off port for the excess gases was moved to the side of the lid with a revolved feature covering the port. This ensures dust and debris would have difficulties entering the sealing chamber, thus removing the chances for dust and debris contaminating the food products. With a spring selection made, a clip in ring was included into the design to allow the selected spring to clip into the lid for ease of assembly for the consumers. Ribs were installed on the prototype at this stage, as the prototyping was completed with additive manufacturing, requiring additional support for the PLA prototype that should not be required on the final stainless-steel product.

V4: With the material selection of AISI 316 stainless-steel made, the model updated for a fourth and final time. This iteration saw a reduction in roof and wall thickness of the design from version three. Since the material was selected, manufacturing could be considered, leading the team to decide on rubber pad forming for the main lid. V4 features the ribs on the interior of the lid, which may be removed from the concept after further discussion with manufacturing professionals. The planned manufacturing method requires the side port to be removed from the model and reattached as an assembly after completion of the rubber forming, thus this has also been incorporated into design choices and considerations.

Component	Poor Design Options	Improved Design Options
Spring  Figure 5: Spring CAD Model	• Torsion or extension spring. • Opened and non-grounded ends. • Using a spring with too high of a spring constant can cause gas in the jar to build up beyond its maximum PSI threshold potentially leading to a jar explosion.	• Compression spring. • Closed and grounded ends provide a flatter surface for the springs to rest between the lid and sealing disk which reduces the chances of the springs wobbling during use [9]. • Using a spring with a spring constant of approximately 7 lbf/in will ensure that the gas in the jar is released well before too much pressure builds up.
Mason Jar Sealing Disk  Figure 6: Mason Jar Sealing Disc CAD Model	• Using a non-food grade material. • Using too large of a diameter can cause the disk to not sit properly on the jar's rim. This can compromise the jar's seal. • Manufacturing the disk to be too thin can cause deformation under high pressure conditions.	• Using a food grade material to avoid any harmful chemicals from leaching into the jar's contents. • Selecting a non-porous material for easy clean up.
Lid  Figure 7: Final Lid Design CAD Model	• Using a non-corrosion resistant material can lead to reduced lifespan due to pitting and/or cracking. • Holes machined in the top of the lid to alloy gas to release.	• Using a corrosion resistant material such as AISI 316 stainless steel [10]. • Machining grooves along the outer perimeter allows for an easy grip design. • A 'hooded' pressure ventilation system machined on the side of the lid to block out contaminants from entering the jar-lid system.

Material Selection

To ensure the fermentation lid-spring system works efficiently and safely, extra care needs to be taken when selecting the type of materials used. The top three properties that our material should have includes being food safe, corrosion resistant and have a moderate to high Young's modulus. Firstly, the material must be food-grade certified to prevent any harmful chemicals from contaminating the contents of the jar. Secondly, it must be corrosion resistant as it will frequently be in contact with acidic gases and liquids. A corrosion prone material can weaken the integrity of the product. Air that enters the jar due to a corroding lid could compromise the fermentation process. Thirdly, the material should have a moderate to high Young's modulus. A high value will ensure that the system remains rigid enough to maintain its shape and integrity under increased pressure conditions. Thus, careful consideration of the above-mentioned properties is crucial to the success of our product. A failing system due to wrong material selection can cause food spoilage and potentially lead to health issues if consumed by users.

Ansys Grata Software

The material selection process of the lid starts with using Ansys Grata software. By using this software, we will significantly reduce the range of available materials to those that are best suited for our application. We begin our research by defining various properties and constraints that the lid should have. This will help us develop a material index(es) to plot in the software.

Required lid properties:

- Have a moderate to high Young's modulus to reduce deformations caused by pressure changes.
- Be corrosion resistant to ensure the functionality of the product throughout its useful life.
- Comply with food safety regulations.

- Weight should be comfortable for the average user to handle.

Lid constraints:

- The lid’s diameter needs to conform to the standardized mason jar rim diameter, 65mm outer diameter.
- The lid’s threading needs to conform to the standardized mason jar threading 6.5mm pitch at 2.1 complete revolutions.

Using a simple stiffness to density material index yields the following equation [11]:

$$M = \frac{E}{\rho}$$

Where E is the Young’s modulus and ρ the density. For our application, the above-mentioned material index should be maximized to determine materials that are stiffer per unit mass. Rearranging the equation and taking the log on both sides yields the following equation that can be plotted in the software:

$$\log M \ = \ \log E \ - \ log\rho$$

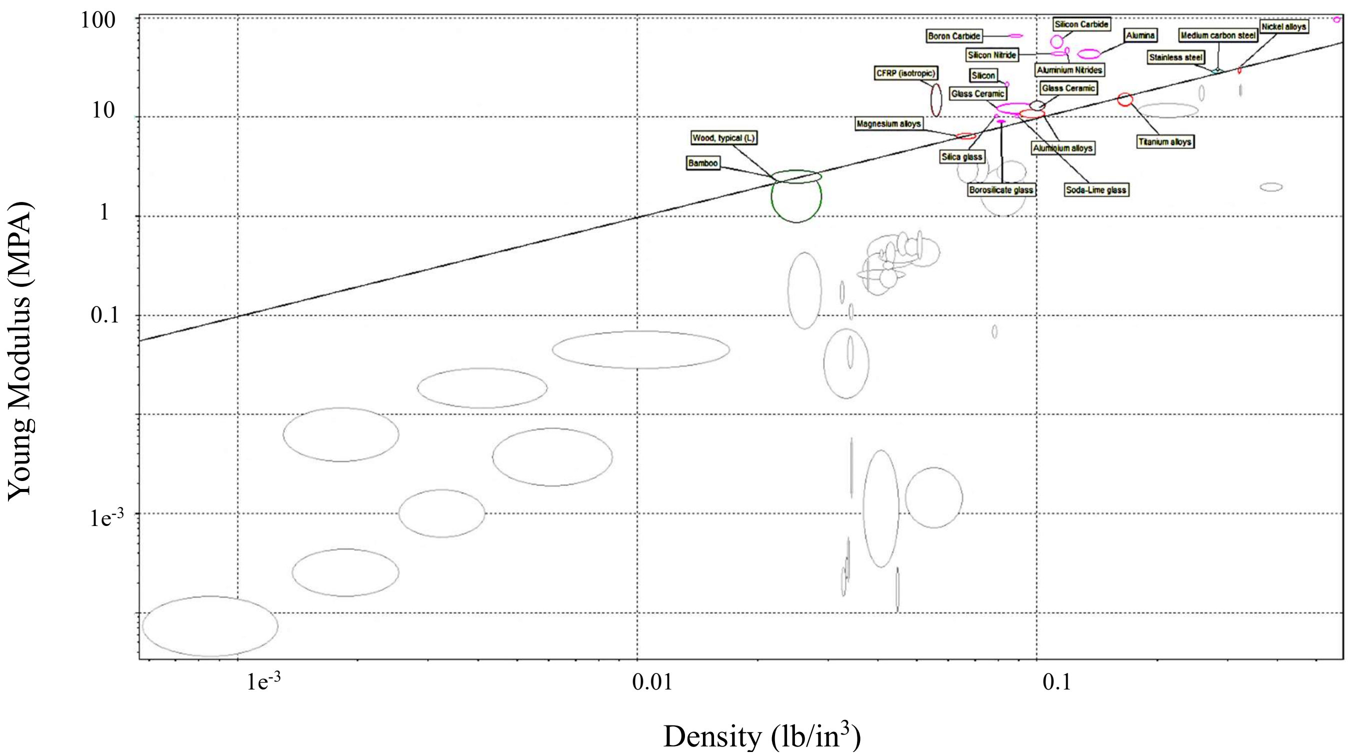

Figure 8: Ansys Material Selection Results.

Per the graph, stainless steels, medium carbide steels and nickel alloys are the top three candidates for materials offering high stiffness-to-weight ratios.

Corrosion Resistance

Among the choices of metals that are notably corrosion resistant are: AISI 316 and AISI 304 stainless steels. Stainless steels mainly resist corrosion due to their ability to form a protective oxide layer through a process known as passivity [10], making them good options for our application. When the chromium content of the stainless steel comes in contact with the oxygen in its surroundings, a metal oxide layer forms on the surface which is undetectable to the naked eye [10]. This oxide layer acts as a barrier that prevents further oxidation and degradation of the metal ensuring its longevity even in acidic environments. Furthermore, the addition of 2-3% molybdenum to 316 stainless steels makes it superior to 304 stainless steels in terms of corrosion resistance. Molybdenum stabilizes the oxide layer making it harder to penetrate through and initiate corrosion [12]. Thus, AISI 316 stainless steels take the lead on a good corrosion resistant material that also has a high stiffness-to-weight ratio.

Food Safe

Our product will be in direct contact with food that users will consumer. Thus, it is imperative to ensure that our selected material is food safe. Materials that are not food safe can release harmful chemicals into the contents of the jars and can lead to health issues, should the spoiled food be consumed by users. Additionally, the material should be non-porous, and non-reactive to ensure that the material remains as sanitary as possible through its useful life. A porous material should be avoided as food particles, debris and/or moisture can get trapped in the material, creating a breeding ground for bacteria which ultimate compromises food safety and hygiene. The American National Standards Institute (ANSI) claims that "stainless steels used in food equipment shall be of a type in the AISI 200 series, AISI 300 series, or AISI 400 series" [13]. Additionally, ANSI also claims that equipment surfaces that intend to be in directed contact with food shall have a minimum chromium content of 16% [13].

AISI 316 emerges as the optimal choice for our product. Not only does it meet the ANSI standards for safe contact with foods, but it also offers superior corrosion resistant compared to other stainless steels grades due to the addition of molybdenum content. Furthermore, 316 stainless steel is non-porous and easy to clean, ensuring that it maintains a high level of hygiene over time. It's high stiffness-to-weight-ration ensures that the material will not deform under high pressure conditions. By choosing 316 stainless steel as our material of choice, we prioritize both the safety of our users and the longevity of our product.

Cost Analysis

Cost analysis is a critical component of the product development, as it determines the feasibility, marketability, and profitability of the product. For the pressure relief fermentation lid, our team has executed a planned cost analysis process, to ensure the product remains affordable for budget home fermenters while maintaining high quality, safety, and reliability. This analysis takes into account all stages of the development process, from material selection to manufacturing. By evaluating these factors, we've managed to optimize our expenses to ensure a specific priority in fulfilling the product requirements. This section will provide a comprehensive breakdown of the costs associated with developing and producing the product, therefore supporting its market value and financial opportunity to users and stakeholders.

Manufacturing Costs

Using a simple input-output model for a manufacturing system we can estimate the manufacturing costs. Handling multiple product lines should be done through monitoring each activity's cost. For instance, considering the first step of manufacturing the lid through punching the metal sheet, costs are involved in the activity with the machinery, raw material, and labor. For monitoring optimization, software can be introduced to track costs by product line, including factors like material usage, processing time for labor cost and machine cycles.

As the production increases, the development cost is gradually absorbed into the production cost of each unit, for example if the development cost amounted to 100.000 $, and the production cycle for this development is expected to output 100.000 units, then each unit absorbs 1$ of the development cost.

In order to define the manufacturing boundaries, choices of internal and external manufacturing are made based on the financial decisions of the company as well the team's expertise. Our team made the choice to internally manufacture the metallic lid and the inner sealing cap using metal forming processes, where 316 stainless steel and sealing gaskets is procured through various suppliers. The spring would be outsourced to an external manufacturer to reduce the costs of labor and machinery.

As part of the cost analysis, our team conducted an in-depth evaluation of the costs associated with purchasing and operating the machinery required for manufacturing the different components of the product. The material selection has led us to various choices of materials that could be used in the manufacturing of the lid like plastic or metal lids. These choices would entail the purchase of injection molding machinery for plastic manufacturing of the lid as well as customized injection molds. Through our research, we have evaluated some North American and Chinese sellers specialized in the manufacturing of these equipment. Injection molding manufacturer machines makers like Milacron, Nissei America, Sumimoto Demag. On the other hand, sheet metal shaping to produce metallic lids involve various processes, including laser cutters or punch presses, rubber pad forming machines and coating machines. As for the spring making, some Chinese made wire spring machines were evaluated for pricing. Estimation from the quotes that we were able to gather from different companies for these machines, are as follow. Injection molding machines for making plastic lids ranging between 20.000-50.000$ plus additional cost of 5000-10.000$ per mold, this option has been discarded since it presents too big of an initial cost. Conventional spring forming machines to make custom springs out of metal wire ranging between 1200-4500 based on the design and capability. A sheet metal punching press with an incorporated die to cut and coin the shape of the inner and outer parts of the lid ranging from 20.00-30.000. Metal forming machines such as a rubber pad forming machine for the wall and threading of the lid ranging from 15.000-30.000 plus 2500$ for each custom rubber pad and die.

As for the machinery purchased for the manufacturing, these types of machines have a total lifecycle around 5 years of heavy use, and up to 10 years for a single shift per day. Therefore, the total cost of the equipment is divided by its total useful life.

Canadian Customs Tariff

To provide a realistic estimate for the material cost of our product, we need to account for the duties and taxes payable to the Government of Canada for importing offshore materials. Firstly, the Harmonized System (HS) code administered by The World Customs Organization (WCO) for "flat-rolled products of stainless steel, of a width of 600 mm or more (not exceeding 1,830 mm) and of a thickness of 3 mm or more but less than 4.75 mm", to be 7219.21.00.10 [15]. This HS code is duty free, although is applicable to 5% Goods and Services Tax (GST). Secondly, the HS code administered by the WCO for helical springs with uses other than for furniture or motor vehicles to be 7320.20.00.90 [14]. This HS code is duty free, although is applicable to 5% GST. An important thing to note, is that the 5% GST paid on these imported goods can be reported and recovered by claiming Input Tax Credits (ITCs) [15]. By claiming ITCs we can offset the GST paid against the GST collected from the end users of our product.

Material Costs

As per the cost of materials, we've been quoted by some offshore metal suppliers that sell the 316 stainless steel sheets for between 0.78-1.49/kg from Shandong Puxin Steel Co., Ltd. excluding shipping, while local suppliers charge between 25-28/kg from Industrial Metal Supply Co. As for the sealing gaskets, we've been quoted by an offshore supplier Hebei Wanyuan Rubber Technology Co., Ltd. around 0.042$ each. Finally, the spring made of 316 stainless steels as well would cost around 4-5 each locally sold by McMaster-Carr, and around 0.056-0.15 with offshore suppliers like Cangzhou Haorun Hardware Products Co., Ltd.

The table below breaks down the manufacturing costs for the main lid components based on the following cost equations [15]:

The raw material cost = (weight of the part + scrap allowance) x cost per weight.

Processing costs = costs of the operator(s) + cost of using equipment.

Total unit cost = ((setup cost + tooling cost)/volume) + variable cost.

<table>
<tr><th></th><th>Fixed costs</th><th>Variable costs</th><th>Volume</th><th>Total unit cost</th></tr>
<tr><td rowspan="2">Lid</td><td>Setup:</td><td>Material: $0.00038 each
15g of 316 SS</td><td rowspan="2">10k
100k
1M</td><td rowspan="2">$0.55
$0.055
$0.0055</td></tr>
<tr><td>Tooling:
$5k rubber pad / die forming
$500 press punch blade</td><td>Processing:
250pcs/hr.
$62/hr</td></tr>
<tr><td rowspan="2">Sealing disk</td><td>Setup:</td><td>Material: $0.00025 each
10g of 316 SS</td><td rowspan="2">10k
100k
1M</td><td rowspan="2">$0.05
$0.005
$0.0005</td></tr>
<tr><td>Tooling:
$500 press punch blade</td><td>Processing:
500pcs/hr
$40/hr</td></tr>
</table>

Table 4: Manufacturing Costs

Cost Model of the Product

Component	Qty/Lid	High ($ each)	Low ($ each)
Lid	1	0.550	0.055
Sealing Disk	1	0.050	0.005
Spring	1	0.150	0.050
Sealing Gasket	1	0.100	0.042
Assembly & Packaging	20$/hr.	15 sec (0.08$)	10 sec (0.05$)
Overhead cost	25%	0.232	0.05
	Total	**1.162**	**0.252**

Table 5: Cost Model

In order to maximize sales, our company will leverage a dual sales approach to reach customers directly, while expanding the market on other fronts. By using an online platform, the product will reach customers directly, especially those experienced and actively looking to improve their experience. Additionally, we will partner with major retail platforms to increase our product's visibility and accessibility to those starting or curious about the process of fermentation. Traditionally, these platforms aim for margin profit of around 40% to 60% of the final retail price.

For a target retail price of 4.99$ on a popular platform, considering an average production cost of $0.71 per item, we would charge retailers around 2.00-2.50$ each. The profit margin for the company on these sale platforms is around 281-352% over the average production cost.

For direct sales, we would charge a more competitive price around 3.99-4.50$ a unit. The profit margin for direct sales is around 562-634% over the average production cost.

Labor Cost for Manufacturing and Assembly

Labor cost for manufacturing and assembly will account for a significant portion of the overall production expenses. The manufacturing would require operating three machines, a rubber pad forming machine, and two punching presses, though these operations require low skilled labor. Each one of the machines typically requires one operator per shift, with an additional worker for material handling, equipment maintenance and quality control. The assembly and packaging process requires a fifth worker to integrate the springs and gaskets and secure the product for delivery. Labor costs for these manufacturing and assembly roles range from $18 to 22$ per hour, factoring in an 8-hour shift, the daily labor cost for operating and supporting production activities can range between $700 and $900 daily.

Operation and Maintenance Costs

There are numerous other expenses in the production process of a product. Ou team estimates these costs based on the requirements of the process. An important factor is power consumption, a rubber pad forming machine and two punching presses typically consume between 5-15 kW each, depending on the size and operation cycles, assuming an average of 10kW per machine through an 8-hour operation shift, daily energy consumption around 240 kWh, which amounts to around $700 per month. Industrial rent rates vary depending on the location, for example a 2,000 square feet estate would cost up to $2000 monthly. Additionally, there are other smaller side expenses to running the operation like maintenance, insurance and utilities that needs to be accounted for.

Cost Drivers and Optimization

To reduce the cost of components for our product, the reams focused on analyzing and optimizing the affordability of the manufacturing processes and design. A particular area of interest was selecting cost-effective production process, for example, deciding to manufacture the lid through stamping and forming of the lid with conventional automatic feed machines, instead of investing in high end precision CNC equipment that would add unnecessary expenses in purchase, operation, and maintenance. Similarly, tolerances were carefully selected without unnecessary complication, avoiding over-engineering of the product, and saving material and production time. Additionally, steps in the processes have been selected to integrate multiple functions at the same process, such as incorporating the threading into the mold to avoid additional forming operations. These measures not only save material costs, but also minimize the processing time, ultimately optimizing the cost efficiency of the manufacturing process.

To further reduce the components cost, our team decided to purchase the springs for the mechanism from specialized suppliers rather than manufacture them in-house. Producing the springs would add additional costs in specialized coiling machinery, and labor, therefore inflating the overhead expenses. By outsourcing the springs to suppliers, we benefit from their expertise and a readily available market.

To reduce assembly costs, our team concentrated on simplifying the assembly process with a minimum part’s count. By integrating features like spring housing in the lid design, the number of assembly parts is reduced, which in turn decreases the time and cost of assembly in production and by the user. Additionally, the choice of design ensures the spring, and the inner plate can be easily snapped or press fitted without the need for any tools or fasteners. The assembly optimization not only reduces production time, but also reduces the potential for mistakes, and simplifies the manufacturing support process. Through the use of DFA index, we can further determine the assembly efficiency as follows [2]:

DFA index = ((theoretical min # of parts) x (3 sec)) / estimated total assembly time

DFA index = (3 x 3)/10 = 0.9

To optimize part integration in the product, our team examined each components necessity of separation and functionality. For our design, the lid, the spring, and the inner cap needed to be separated into different units since they all require relative motion as well as different manufacturing materials. On the hand, the opening for the pressure relief was incorporated into the structure of the outer housing of the lid to eliminate the need for an additional separate component. These part integration choices ensure a minimum part’s count, reducing the assembly time and the complexity while allowing for ease of access to clean and replace components by users.

Testing and Validation

Overview

Several different tests were performed during the testing and validation phase of the product to ensure compliance of the product with the requirements discussed previously. A test report, which is included in this section, provides a detailed description of the tests conducted and their results. Tests conducted include performance, pressure, and leak tests. Additionally, visual inspections were conducted on the prototype and all other materials used, prior to and after each test. Photographs and videos were used during testing to document results.

It should be noted that, due to time, cost and availability constraints, the intended material selected for the design, stainless steel 316, was not used for the prototype used during the initial product testing phase. Instead, testing was conducted with the fermentation lid made of PLA+ and the spring was made of stainless steel 316, as alternative materials.

Performance Test

Performance tests conducted found that, when compared to a control jar, the product had shorter gas purge durations and was easier to open during the fermentation process. Results showed that, while both the control and test jars were effective in their use during the fermentation cycle, the product was advantageous in its limiting of pressure build-up. This supports one of the primary goals of the product, to make fermentations more autonomous by self-regulate its pressure.

Pressure Test

Pressure tests were conducted to verify that the lid could withstand the build-up of internal pressure by allowing gases to escape once a specific pressure threshold is exceeded. The pressure threshold is determined by the stiffness of the compression spring. If the spring used has a spring constant, or stiffness, that is too high, the spring would require a higher force to deform and allow the escape of excess gasses. Using a spring with a spring constant that is too low would prevent the lid from maintaining the airtight seal that is necessary during the fermentation cycle, allowing air to enter and gasses to escape.

In this test, a vitamin C tablet was dropped into a mason jar half-filled with water and the fermentation lid was used to seal the jar. The jar was then monitored for signs of gas buildup and release. Testing found that there were instantaneous signs of gas build-up, by the visible production of bubbles. The venting of gases could also be heard and occurred in intervals that gradually decreased over time.

Leak Test

Leak tests were performed to evaluate the leak proof integrity and airtight sealing capabilities of the product. This was done by filling a mason jar with water, leaving a one-inch gap at the top, and installing the fermentation lid onto the jar. The jar was then flipped upside down and monitored every five minutes for a total of 30 minutes. After 30 minutes, the jar was flipped right side up lid was removed and checked for the presence of water.

Following this, the lid was re-installed, and the jar was fully submerged into a large pot of water for 10 minutes and monitored for any escaping air bubbles or other signs of seal failure. Results found no signs of leaking.

Overall testing outcomes leads to the conclusion that the fermentation lid has successfully met its given requirements. However, another series of testing will be required once the final prototype has been manufactured, using the selected materials.

Test Report

1. AIM

The aim of this report is to summarize the observed performance and practicality of the fermentation lid, focusing on sealing, gas release and handling.

2. BACKGROUND

The popularity of the fermentation process has reemerged in recent years, likely due to its many benefits. Fermentation allows for easier digestion of nutrients, by breaking them down, and improves the overall nutritional value of foods. Fermentation also limits waste by preserving foods for longer periods of time and alters their natural flavors. Unfortunately, fermentation can be a time-consuming activity and requires regular monitoring.

Many different products are available to aid in this process, including fermentation lids. Most fermentation lids, however, are often bulky, expensive and difficult to clean. By considering the current needs of consumers, Seal of Approval INC. set out to design a simple, affordable, lid that requires little additional space than a standard mason jar band, and little to no maintenance between uses.

3. DESCRIPTION OF UNIT UNDER TEST (UUT)

3.1. Fermentation Lid

The mason jar fermentation lid, referred to in this report as Unit Under Test (UUT), is comprised of a lid and a spring. It utilizes the mason jar seal provided with the jar. It can be fitted onto various sizes of standard regular-mouthed mason jars.

Design plans for the UUT use 316 Grade Stainless Steel; however, the UUT used when conducting the tests included in this report is made of PLA+, and the spring is made of 304

Grade Stainless Steel. Figure 9 shows a sectioned view of the UUT prototype design used in testing.

Figure 9: UUT CAD Model Section View

3.2. Dimensions

Component	Dimension	Material
Lid	Outer Diameter: 3” Inner Diameter: 2.75” Height: 1” Thickness: 0.08”	Stainless Steel – 316 Grade
Spring	Outer Diameter: 1.495” Inner Diameter: 1.32” Wire Diameter: 0.085” Length: 1.03” Spring Constant (k): 8 - 10 lbf/in	Stainless Steel – 316 Grade

Table 6: Required Dimensions

3.3. Additional Items

All relevant information relating to any additional items used during testing can be found in Table 7.

Item	Description	Dimensions	Material
Jar	16 oz Regular-Mouth Mason Jar	Height: 127 mm Inner Diameter: 60 mm Outer Diameter: 70 mm	Glass
Jar Seal	Regular-Mouth Mason Jar Seal	Diameter: 60 mm	BPA Free Silicone Stainless Steel – 304 Grade
Jar Band	Regular-Mouth Mason Jar Band, Threaded	Diameter: 50.8 mm Outer Diameter: 60 mm	Stainless Steel – 304 Grade
Weights	Mason Jar Fermentation Weights	Diameter: 2.1” Height: 1.1”	Glass

Table 7: Additional Items Used during Testing

4. SAFETY

All testing involving high pressure will be conducted using proper safety precautions, including PPE.

All materials used should be compliant with food safety guidelines.

Jars, seals, and fermentation lids should be visually inspected before and after all tests, checking for cracks, dents, wear, damage or blockages.

5. PERFORMANCE TEST

5.1. Acceptance Criteria

Performance test requirements to be satisfied included the following:

a) The duration of the gas release of UUT should be significantly shorter than control.

b) UUT is expected to be opened with less effort than control during gas purges.

5.2. Functionality/Overview

In order to accurately determine the effectiveness of the fermentation lid, it was subjected to a fermentation cycle. A second fermentation, started in parallel using a classic mason jar seal and band, was used as a control.

5.3. Set-Up/Installation

Two standard mason jars were filled with identical ingredients, in similar quantities, and left over a two-week period to observe the performance of the fermentation lid when compared to a traditional mason jar seal and band.

5.4. Test Procedure

Two sterilized mason jars were filled with similar quantities of washed produce, and approximately 1 inch of space was left at the top of each jar. Jars were each weighed, filled with water until approximately 0.5 inches of space was left, and re-weighed. The weights were used to calculate the weight of water added. Salt equal to 3.5% of the weight of the water in each jar was added to create a 3.5% brine. The jars were then sealed with the seals provided, and the fermentation lid was placed on the test jar, while the standard mason jar band was placed on the control jar. Both jars were then left out to allow for the fermentation process to take place.

After two days both the band of the control and the fermentation lid were both loosened to allow gases to escape. Both purges were recorded and timed. Lids were retightened and the jars were again left to ferment. Gas purges were done every 2-3 days, for 16 days.

Once the fermentation cycle was completed, jar contents were inspected, looking for any foul or rotten odors, mold or slime growth and discoloration of the produce. The pH level of the brines was taken and compared.

The contents of the jars were then blended with some of their brine equaling to 10% of the content weights.

6. PRESSURE TEST

6.1. Acceptance Criteria

Pressure tests were conducted to verify that the lid could withstand the build-up of internal pressure by allowing gases to escape once a specific pressure threshold is exceeded.

6.2. Functionality/Overview

The pressure threshold is determined by the stiffness of the compression spring. If the spring used has a spring constant, or stiffness, that is too high, the spring would require a higher force to deform and allow the escape of excess gasses. Using a spring with a spring constant that is too low would prevent the lid from maintaining the airtight seal that is necessary during the fermentation cycle, allowing air to enter and gasses to escape.

6.3. Set-Up/Installation

This test requires a clean mason jar, partially filled with water, the fermentation lid and a vitamin C tablet.

6.4. Test Procedure

In this test, a vitamin C tablet was dropped into a mason jar half-filled with water and the fermentation lid was used to seal the jar. The jar was then monitored for signs of gas buildup and release.

7. LEAK TEST

7.1. Acceptance Criteria

Leakage tests were performed to confirm that the UUT satisfied the following criteria:

a) Air-tight sealing: the UUT can maintain an airtight seal under normal conditions.

b) Leak-proof integrity: no liquid or gas can escape the jar before the fermentation process has begun.

7.2. Functionality/ Overview

To ensure that the UUT is capable of meeting the requirements mentioned in 7.1. a series of tests were performed to observe the behavior of the UUT under normal conditions.

7.3. Set-Up

This series of tests required a mason jar to be filled with water. A large pot of water was used during the leak-proof integrity portion of testing.

7.4. Test Procedure

A mason jar was filled with water, leaving approximately 1 inch of space at the top. The seal and UUT were then fitted onto the jar. Any excess water on the test materials was dried prior to testing.

a) The jar was first flipped upside down and left in this orientation for 30 minutes. An initial inspection of the UUT was done, checking for any immediate signs of leaks. It was then checked every 5 minutes. After 30 minutes the lid was removed and inspected for the presence of water.

b) The lid was re-fitted onto the jar and a large pot was filled with enough water for the jar to be fully covered. The jar was then submerged into the water and monitored for any escaping air bubbles or other signs of seal failure.

8. VISUAL INSPECTIONS

8.1. UUT

The UUT was washed and dried before and after each test, and inspected for any signs of damage, wear, and blockages of the air/gas escape vent. Visual inspections were again conducted after the completion of each test.

8.2. Additional Materials and Equipment

All jars, seals and bands were washed before use. Jars were sterilized when used for fermentation cycles involving any food or brine. All additional materials were inspected prior to and after each use for any cracks, signs of wear or damage, or other defects.

8.3. Photographs and Videos

Photographs were taken to document the process, set-up and results of testing. Videos were taken when applicable.

9. RESULTS SUMMARY

9.1. Performance Test Results

Table 8 presents the results collected during the performance tests of the UUT. It should be noted that the test jars were subjected to a temperature change between the third and fourth set of purges, due to them accidentally being placed in the fridge for 36 hours.

Date	Duration of Purge (s)		Intensity of Gas Release (High, Moderate, Low)		Difficulty of Jar Opening (High, Moderate, Low)	
	Control	Test	Control	Test	Control	Test
05/11/2024	N/A	N/A	N/A	N/A	Low	Low
07/11/2024	60	10	High	Low	Moderate	Low
10/11/2024	75	15	High	Moderate	High	Low
13/11/2024	150	20	High	Moderate	High	Low
18/11/2024	160	45	Moderate	Low	High	Low

Table 8: Performance Test Results

Figures 10 and 11 show the filled control and test jars, on the first and last days of testing. It should be noted that jar weights were added after the second set of purges were performed, to keep the produce below the brine, preventing the growth of mold.

Figure 10: Filled Test (Right) and Control (Left) Jars on 05/11/2024

Figure 11: Test (Right) and Control (Left) Jars on 18/11/2024

Figures 12 through 16 show the contents of each jar after the fermentation cycle was completed.

Figure 12: Control of Jar Contents

Figure 13: Control Brine pH Test Results

Figure 14: Test Jar Contents – Unsliced Peppers

Figure 15: Test Jar Contents – Sliced

Figure 16: Test Brine pH Results

Figures 17 through 21 show the comparison of the Control and Test jar brine results and final blends post fermentation cycle.

Figure 17: Control (Left) vs Test (Right) Brines – Front View

Figure 18: Control (Left) vs Test (Right) Brines – Top View

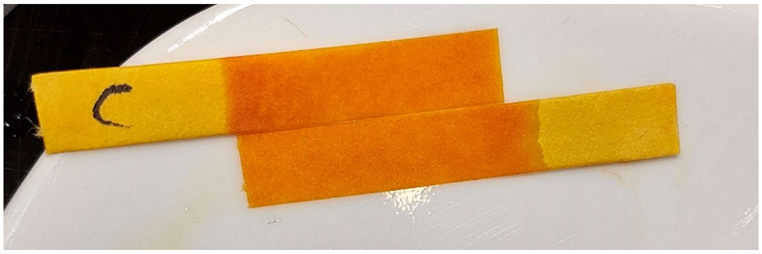

Figure 19: Control (Top) vs Test (Bottom) pH Test Results

Figure 20: Control (Right) vs Test (Left) Blends – Front View

Figure 21: Control (Right) vs Test (Left) Blends – Top View

9.2. Pressure Test Results

Testing found that there were instantaneous signs of gas build-up, by the visible production of bubbles. The venting of gases could also be heard and occurred in intervals that gradually decreased over time.

9.3. Leak Test Results

Leak tests found no signs of leaks when the fermentation lid is properly installed.

10. RECOMMENDATIONS FOR FURTHER TESTING

a) Temperature Variations: Thermal stress testing by temperature cycling, then repeating air-tight sealing, pressure, and leak tests.

b) Overpressure: Determining the maximum amount of internal pressure that a mason jar can withstand.

11. CONCLUSIONS

Data collected during testing of the UUT supports the conclusion that the fermentation lid designed successfully met requirements and can be considered an effective tool for fermentation.

Testing of a final manufactured product, using the selected materials is required. Further testing proposed in Section 10 would be beneficial to ensure that a thorough collection of product specifications and limitations are available.

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Appendices:

Figure 22: Concept 1 CAD

Figure 23: Concept 2 CAD

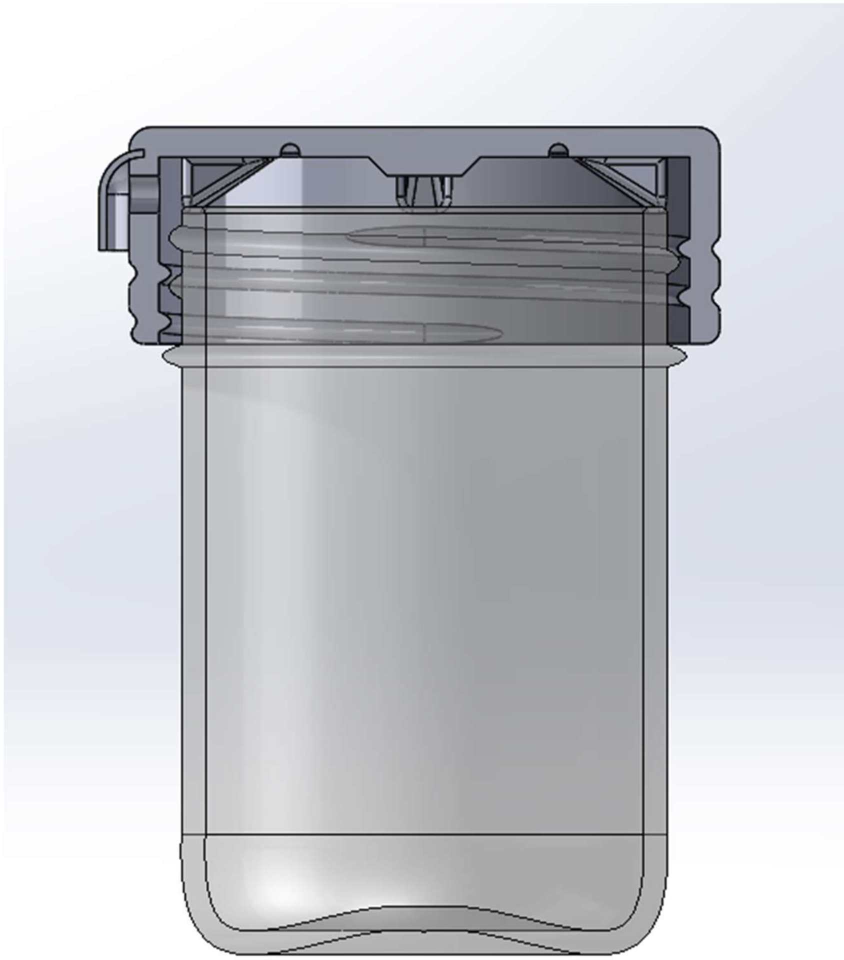

Figure 24: Concept 3 CAD

Figure 25: Concept 4 CAD

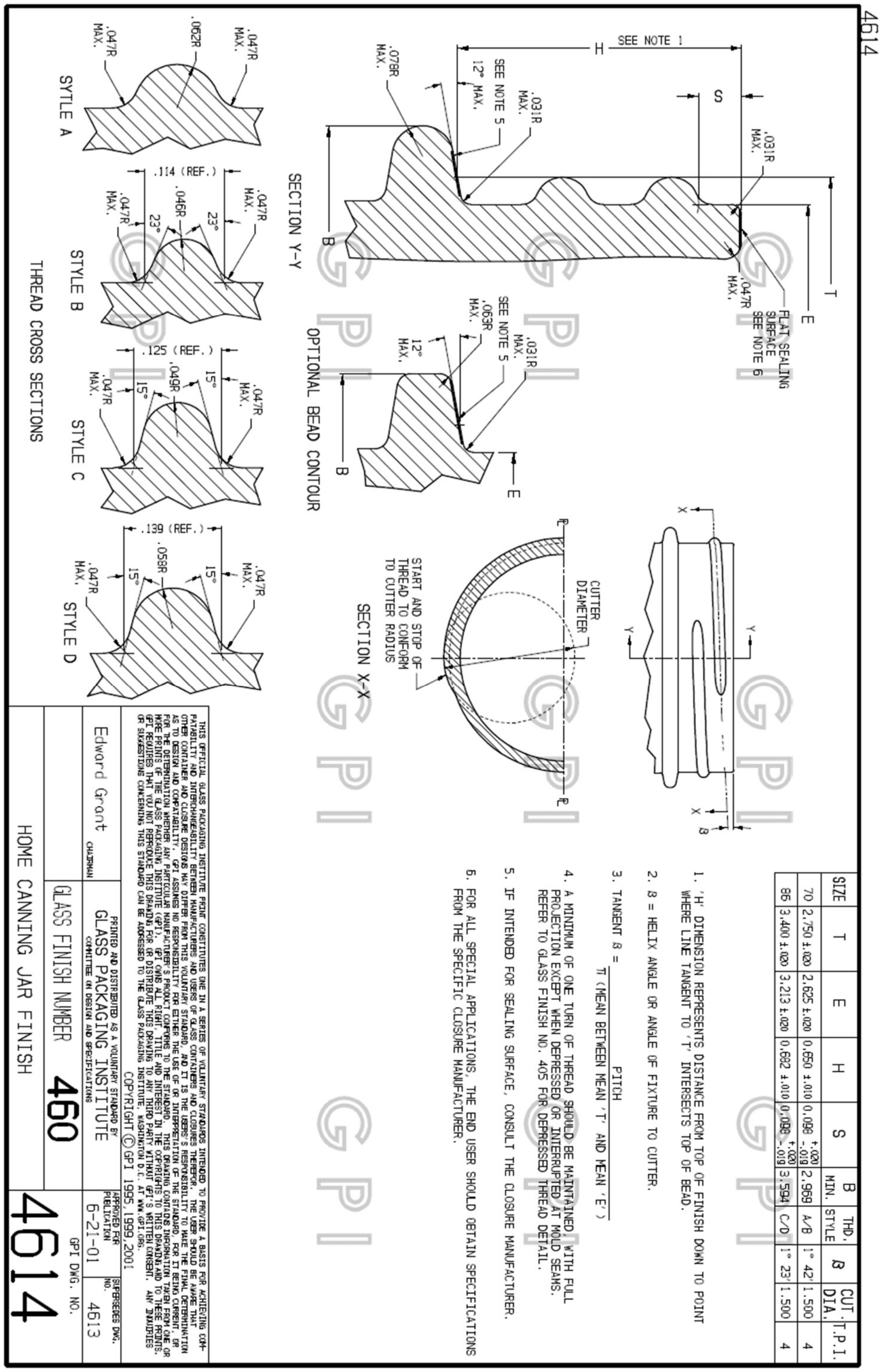

Figure 26: GPI Engineering Drawing of Standard Mouth Mason Jar Threading

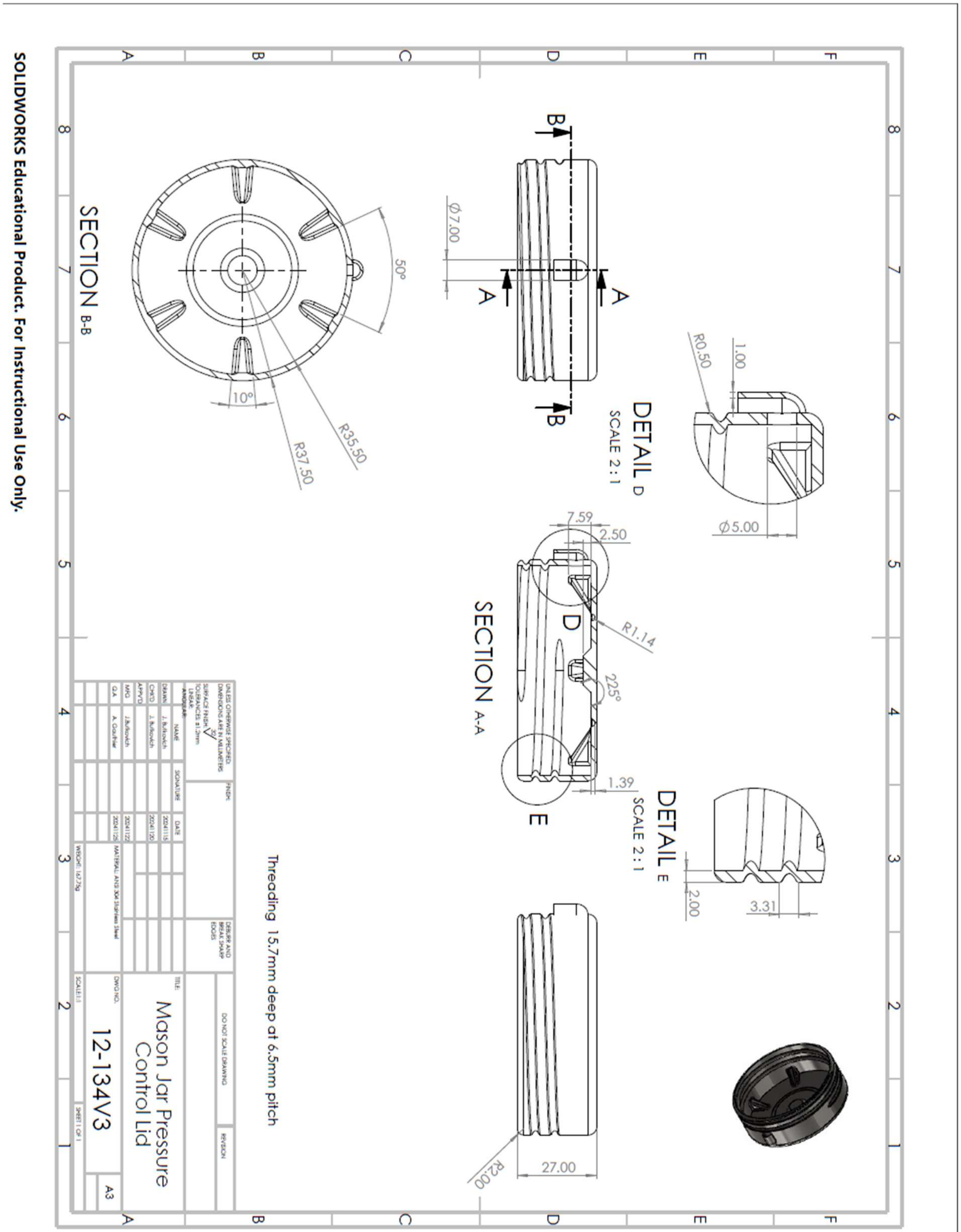

Figure 27: Technical Drawing of Final Concept

Team Member Contribution

Team Member	Responsibility	Contribution
Jon Butkovich	Design and Prototyping	20%
Amelia Gauthier	Testing and Validation	20%
Mohamed Kerir	Cost Analysis and Optimization	20%
Samantha Marcogliese	Manufacturing and Material selection	20%
Kyle Segal	Market Analysis and Customer Relations	20%