Pressurized Strainer for Greek Yogurt Production

Group 21: Cecilia Zafiris and Laura Kennedy
Department of Bioresource Engineering
McGill University, Montreal

ABSTRACT

Greek yogurt is an increasingly popular health food product in Canada, and is produced by separating whey from regular cultured yogurt. There is currently no equipment for whey separation available for medium scale yogurt producers, since large industrial machines are prohibitively expensive and often inconvenient, and passive straining is prohibitively slow. The purpose of this project was to design and implement an efficient and inexpensive machine to remove whey from yogurt for a local dairy company, Cult Yogurt. An iterative design and testing process was used to develop a full-scale design of a pressurized strainer which features a pneumatic press, a cylindrical strainer layered with nylon mesh, and a suction pump. The design meets a number of criteria and constraints including production capacity, food safety, and labour requirements. Results from prototype testing and modeling show that process time for a 350 L batch of yogurt can be reduced from overnight to 46.8 minutes, which greatly exceeds the design goal of a 3-hour process time.

Table of Contents

1 Introduction

Greek yogurt, also known as strained yogurt, is an increasingly popular health food product on the North American market (Conick, 2015). The production of Greek yogurt has three main steps: heat treatment, fermentation, and straining. Heat treatment includes pasteurization and denaturation of the milk proteins. Fermentation is the microbial conversion of lactose to lactic acid, which in turn causes the denatured milk proteins to coagulate. This process results in a homogeneous mixture of yogurt gel (coagulated milk proteins) and whey serum (water with lactose and soluble proteins). The physical separation of whey serum from the yogurt gel is the straining step, which is unique to Greek yogurt (Chandan and O'Rell, 2006).

The purpose of this project was to develop a solution to improve the straining process for a medium-scale Greek yogurt company, as they have identified the straining process as the limiting step in their production line. The proposed solution is a pressurized strainer powered by a pneumatic cylinder. This design was influenced by several designs in the literature review and chosen using two evaluation procedures and an iterative design process.

1.1 Client Overview

Cult Yogurt is a startup dairy company located in Saint-Aimé, Quebec specializing in Greek yogurt. The company produces 350 litres of Greek yogurt from 700 litres of whole Jersey milk each week. The high market demand has the company selling all of their product every week, however they are unable to increase production due to the slow process of straining yogurt after fermentation.

The company currently uses the traditional passive straining process; yogurt is poured into twelve plastic strainers, each lined with nylon mesh, and left overnight to drain. Syneresis (expulsion of whey from the gel) occurs naturally and whey drains under the force of gravity. However, this process is time- and labour-intensive and poses a high risk of contamination, since the product contacts many different surfaces. Furthermore, this method produces an inconsistent product because the removal of whey is not controlled.

2 Literature Review

2.1 Existing Technologies

The method currently used by the client, as previously described, is passive straining. Other technologies on the market are centrifugal separation, ultrafiltration, and the filter press. These technologies are generally used by large-scale yogurt companies and are not suitable for the client.

Centrifuge

The centrifuge design separates substances with different densities. The yogurt is placed in the center of a rotating cylinder which is then spun, forcing the lighter whey molecules to separate from the heavier milk proteins and fats that make up the yogurt gel (GEA Group, 2016).

This technology is not only prohibitively expensive, but impractical for a medium-scale company in terms of size, labour, operating cost, and maintenance. In addition, the client is reluctant to use molecular separation methods as opposed to separation by syneresis because it could affect the final quality of the product.

Ultrafiltration

Ultrafiltration is a method where yogurt is forced through a fine filter under high pressure. Smaller molecules (water, lactose and whey protein) pass through the pores of the filter and larger molecules (milk proteins and fat) are retained (GEA Group, 2012).

Like the centrifugal system, ultrafiltration is expensive and impractical and was rejected by the client and the design team.

Filter press

Another mechanism that is used in the food industry to separate liquids from solids is the filter press. Similar to the passive method, the filter press depends on the natural syneresis of the gel and whey. In this design, bags made of cheesecloth are filled with yogurt. The bags are then pressed one against the other by two end-plates connected to a pneumatic ram and according to a pre-set pressing program. When enough whey has been drained, the set of bags with the Greek yogurt inside is pushed outside the filter onto a bag trolley (Tecnal Products, 2016).

The filter press is not suitable for the client as it is too expensive and involves the transfer of the yogurt from the large 350 litre container to multiple smaller bags, which poses a greater risk of contamination since it comes in contact with more surfaces.

In conclusion, these three technologies are efficient and useful, but they are expensive and not suitable for a medium-scale dairy company. A patent review was therefore conducted to generate ideas for a new strainer design.

2.2 Patent Review

To get ideas for the design of the pressurized yogurt strainer as well as to get detailed specifications on certain features of the design, the following patents were consulted.

Stirring Coffee Press

This patent represents a stirring coffee press for brewing beverage grounds, while simultaneously compressing and agitating the grounds in a single container. The stirring coffee press includes a container with a fitted lid, a plunger assembly within the container which is attached to a shaft, and a blade assembly attached to the shaft that extends and exits through the hollow shaft of the plunger assembly (Brandy, 2002).

The most important feature of this patent that was considered being used in the yogurt strainer design is the plunger assembly since it can be taken apart and be cleaned easily to avoid any food contamination. The plunger assembly is constructed of three components: a flexible metal mesh, a rigid metal disk with holes that holds the mesh in place on the top, and a rigid metal disk on the bottom. The mesh which is the screen material has a flexible tapered end that goes along the perimeter of the container making the system easier to slide down as well as prohibit any granules to get through the sides. This device is illustrated in figure 1.

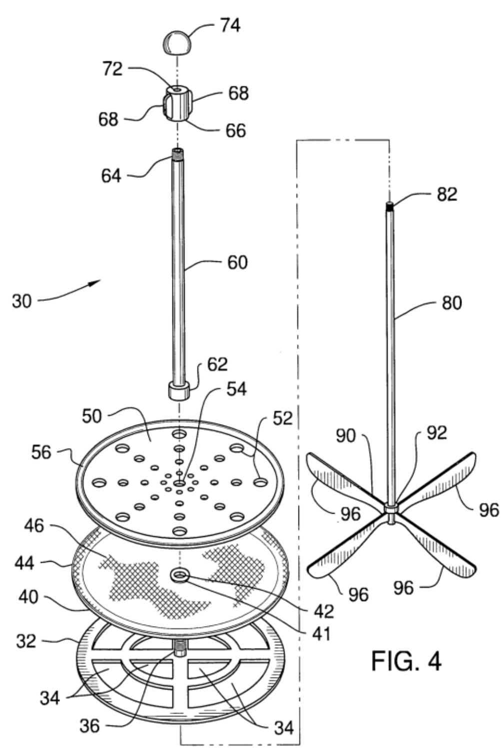


Figure 1: Stirring coffee press.

Yogurt separator device

This design is a passive yogurt separator device (meaning that it uses gravity to separate the liquid from the solid) having a flat blank filter mesh made of synthetic resin and having openings of 200 microns to 400 microns in size. The blank is formable into a yogurt-receiving container for separating the whey from the yogurt (Freeman, 1987).

Although this yogurt separator is a passive yogurt strainer and not a pressurized one, the information extracted from this design was the opening size of the mesh as well as its material. This device is illustrated in figure 2.

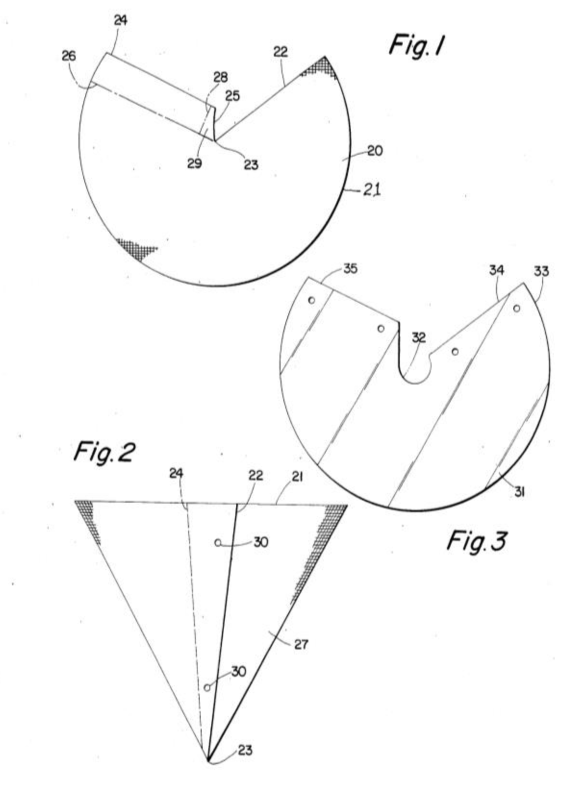


Figure 2: Yogurt separator device.

Portable cheese press frame assembly

This patent is a portable assembly for supporting cheese hoops as well as pressing out the whey from these cheese hoops. The frame includes support members for the hoops as they are compressed by cylinder and piston units located at the top of the assembly. The gases used in the cylinder and piston units are discharged to the floor of the apparatus, preventing their contaminating the hoops or curds that would be possible by release above those hoops (Smith, 1984).

The information extracted from this patent is the design and placement of the cylinder and piston units in order to prevent any yogurt contamination in the pressurized yogurt strainer. This device is illustrated in figure 3.

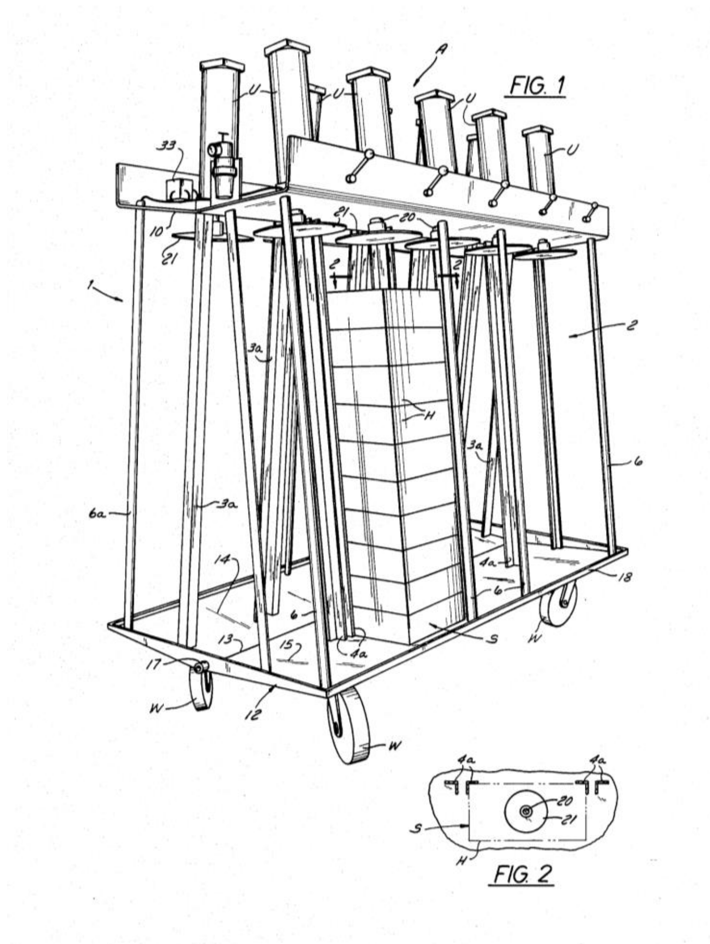


Figure 3: Portable cheese press assembly

Yogurt cheese making device

This design is a yogurt cheese making device for separating the whey from the yogurt through passive straining. The strainer has an open top, a bottom, a pair of opposing end walls, and a pair of opposing side walls. The side walls and bottom are covered with a straining medium which is a wire mesh. The wire mesh is disposed at a 45° angle with respect to the vertical to assist in drainage. The bottom of the strainer is defined by a pair of parallel straining troughs. Whey from the yogurt seeps through the straining medium and is collected at the bottom of the sealable container. The entire device is square or rectangular in shape to minimize the storage area required in a refrigerator (Grusin, 1994).

What was extracted from this patent was the position and design of the wire mesh which is disposed at a 45° angle. The increased surface area as well as the ‘point’ created in the mesh could also assist in the drainage of the whey from the yogurt in the pressurized yogurt strainer. This device is illustrated in Figure 4.

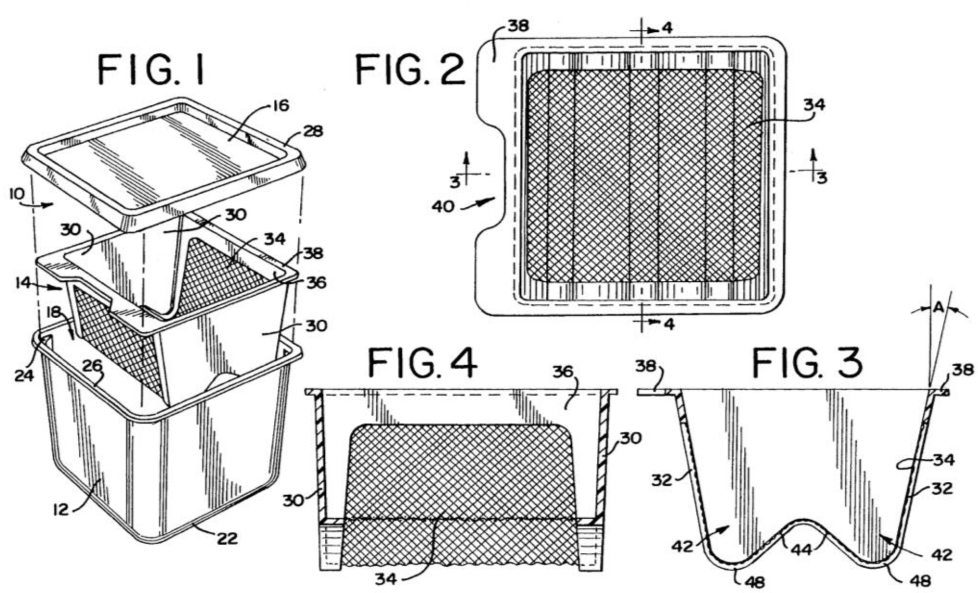


Figure 4: Yogurt Cheese Making Device

3 Design process

3.1 Design Criteria

The design of the yogurt strainer needs to meet the following criteria, which were specified by the design team and the client:

Large Container

The yogurt needs to remain in the 350 litre container in which it is fermented, in order to reduce manual work and decrease the risk of contamination while transferring the yogurt from one container to another, or to multiple containers.

Material

The material used to construct the strainer needs to be food safe. This means that the material chosen should be nontoxic, smooth, nonabsorbent, and corrosion resistant (Chandan and O'Rell, 2006). The material used to build the strainer should meet the Canadian standards for food safety.

Labor

Currently, there are not more than two operators at a time working at the facility. The design should be operable by one or two people, and should minimize the labour required, such as cleaning, by those operators.

Time

Currently, the time required to strain 350 litres of yogurt is about six hours. The main requirement by the company is to decrease production time and since straining is the most time consuming step, this technology needs to be able to strain yogurt in less than three hours.

Cost

The cost of this machine needs to be significantly lower than the machines used in large companies, specifically less than 30,000$ (Alibaba.com, 2016). However, the exact price was not specified by the client.

Consistency

One problem with the current straining method is the inconsistency between batches. There is always human error when pouring the yogurt into the straining boxes, and it is very time consuming to measure the whey removed from all these twelve straining boxes. Consequently, the consistency of the yogurt is usually judged visually. Therefore, this design should help control the quantity of whey removed from the yogurt to always yield a consistent result.

Maintenance

The design needs to be low maintenance in order to minimise repair costs, as well as to minimise the labor needed to clean the machine. In addition to these constraints the densities of whey and yogurt were taken into consideration. Specifically, whey is lighter than yogurt and naturally floats to the surface. This aspect led to the conclusion that it is easier to remove liquid from the top surface of the yogurt rather than the bottom. Using this method also enables the yogurt to remain in the fermentation container which only has an opening at the top. Furthermore, the company already owns a peristaltic pump making it easy to remove the whey after it has been separated.

3.2 First Evaluation Procedure

According to the above criteria and during the brainstorming process the following solutions were considered:

1. Changing the composition of the yogurt by adding dairy powders or concentrating the milk, thus eliminating the straining process altogether (Karam et al., 2013). This idea was rejected because the client did not want to change the texture or composition of their product.

2. Using a hydraulic pressure system to apply pressure on the surface of the yogurt. This was not a viable option since the fluid in the hydraulic pump may cause contamination and is not considered food safe.

3. Using a foot pump to apply pressure on the surface of the yogurt. This idea was dismissed since it is more labor intensive than using a pneumatic pump, and it would be unnecessary to buy such a device since a pneumatic pump already exists in the company's facilities.

The other ideas that were considered and will be explained more in depth are the following three designs: a screw top design, a lever design and a pneumatic pump design which are illustrated in figures 5,6, and 7 respectively.

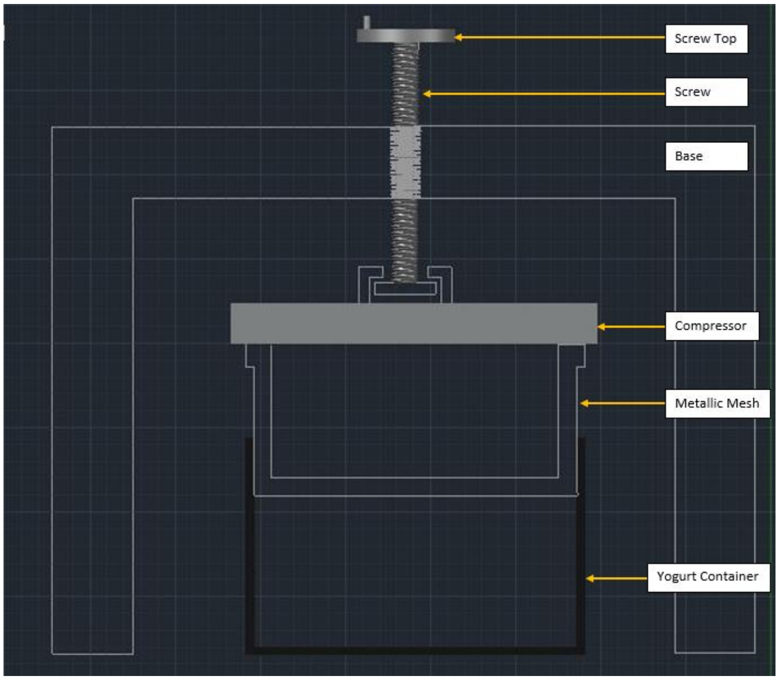


Figure 5: Screw Top Strainer

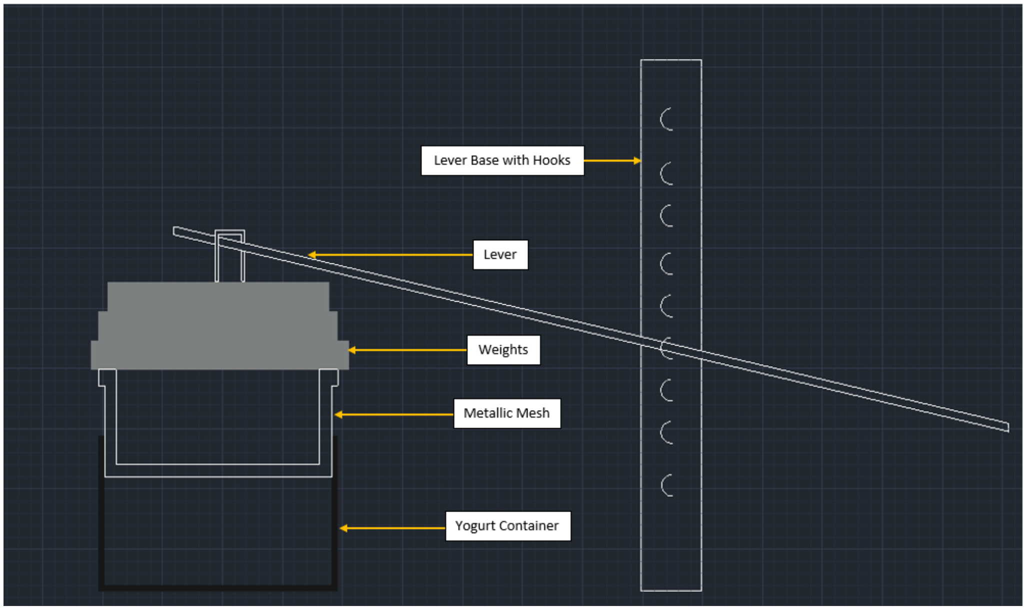


Figure 6: Lever Strainer

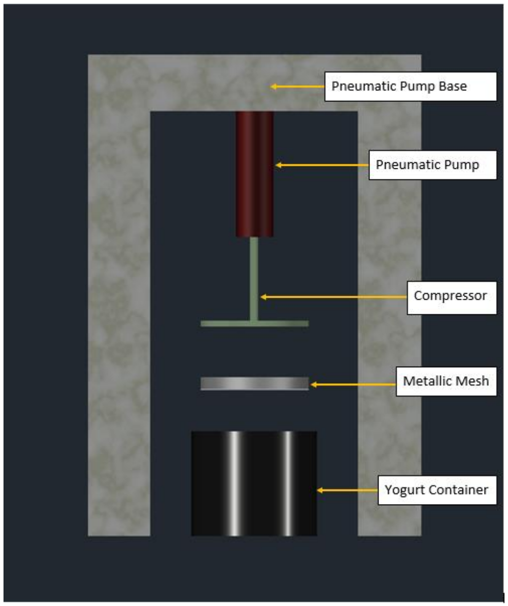


Figure 7: Pneumatic Pump Strainer

3.3 Second Evaluation Procedure

The screw top, lever and pneumatic pump ideas mentioned above each apply pressure using a different mechanism. They represent various technologies that separate liquid whey by applying pressure to a mesh membrane at the surface of the yogurt. Whey is forced to the surface of the membrane where it can be drained using a peristaltic pump. In order to compare the designs and decide on the most appropriate one, a Pugh chart was used. All the mechanisms were ranked in comparison to the current passive strainer used by the company.

Pugh Chart and Weights:

The criteria were given a weight from one to two, with one being not very important and two being very important. Each criterion was assigned that weight according to the priorities specified by the client. The time efficiency was given a weight of two since it was the main requirement by the client in order to scale up their production. The labor intensity was also given a weight of two since there is a limited amount of operators, therefore if the labor demand was to increase the production time would decrease and therefore the main goal of this design would not be achieved. The sanitary material and the facility to clean the mechanism were ranked also as very important and given a weight of two since the machine has to be food safe by law in order to be approved for operation (Canadian Food Inspection Agency, 2016). The cost, was given a weight of one because all of the three design ideas would cost approximately the same to manufacture since they have similar components, and furthermore the client did not give any information on the budget. Finally, the consistency of the resulting yogurt was placed second in importance since that could be adjusted by another step in the procedure of making the yogurt. The Pugh chart and the comparison of the three mechanisms are shown in Table 1.

		Current Method	Design Ideas		
Description	**Weight**	Passive Strainer	Screw Top	Lever	Pneumatic Pump
Time Efficiency	2	0	+	+	+
Minimal Labor	2	0	+	+	++
Consistent Product	1	0	0	0	+
Easy to Clean	2	0	+	+	+
Cost efficient	1	0	--	--	-
Sanitary Material	2	0	0	0	0
Maintenance	1	0	-	-	-

Score	**Weight**	Gravity Strainer	Screw Top	Lever	Pneumatic Pump
+	/	0	6	6	9
0	/	0	3	3	2
-	/	0	3	3	2
net	/	0	3	3	7

Table 1: Pugh chart.

Legend:

Weight: 1= Not very important, 2= Very Important

Evaluation Ranking:

+= better than current method, ++= better than other proposed solutions, 0=neutral

Based on the Pugh chart scores, the pneumatic pump mechanism was chosen as the final solution. This design scored best for labor requirement, consistency, and cost, and it scored equally as well as the other designs for time efficiency, sanitary material, and ease of cleaning. This design was particularly attractive because the company already had a pneumatic pump for cheese pressing, so the pump would only need to be adapted to be used for yogurt straining. The design of the pneumatic pump structure is shown in figure 8.

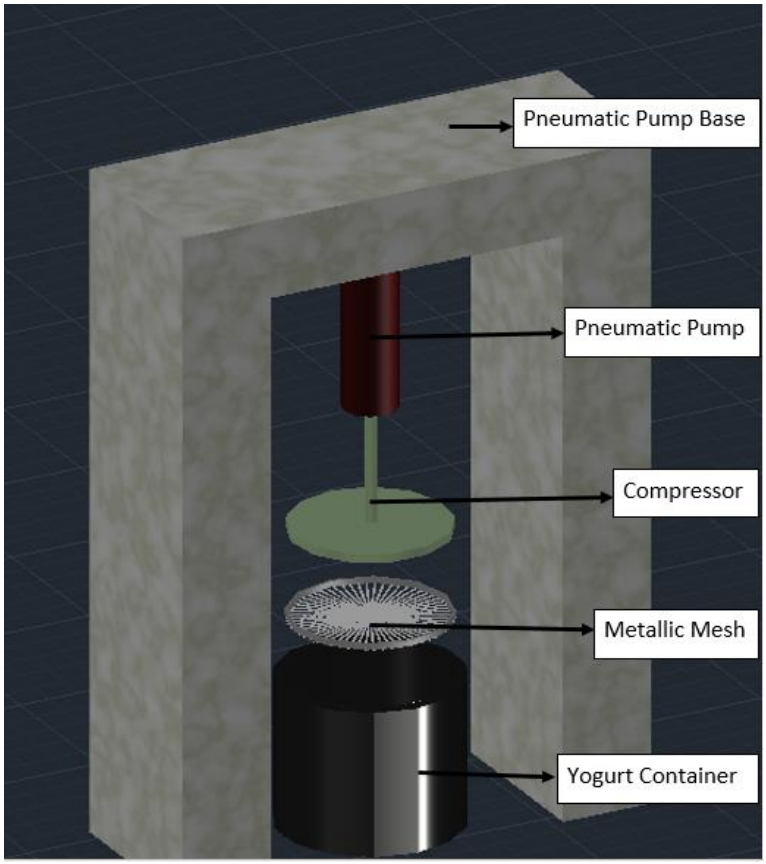


Figure 8: Pneumatic Pump Design

3.4 Testing and optimization

An iterative process was used to determine the shape and material of the mesh, and the pressure required to effectively and quickly strain yogurt. These parameters were used to build a working prototype.

Material

An experiment was conducted with several types of mesh to determine which type of straining material produced the best results. The original prototype was simply a coffee press with a flat straining surface, as shown in Figure 9. The coffee press was used with five different types of mesh to determine which type worked best, and a passive straining system was also tested. The experimental method was as follows: the coffee press was filled with 500 mL of yogurt, the mesh plate was lined with a filter, and then pressure was applied to the press for 5 minutes. The volume of whey removed was recorded for each trial. The results in Table 2 showed that the nylon mesh had the best result among the materials tested. However, in general the straining process was only slightly faster than the passive method, whereas the design criteria required the system to be at least twice as fast as the current one. At the end of the experiment, the design team tried using a cheesecloth bag to strain 500 mL of yogurt and noted that the results were much better than all the other trials. This led to the conclusion that the strainer surface area needed to be increased in order to meet the design criteria.

Figure 9: Coffee press apparatus used for testing different mesh materials.

Trial	**Whey volume (cups)**	**Whey volume (mL)**
Coffee press alone	Not fine enough; yogurt passed through the mesh	
Coffee filter	just under 1/4 cup	60
2.5 micron filter	Too fine; nothing passed through the filter	
100 micron filter	Not fine enough; yogurt passed through the filter	
Nylon mesh	3/8 cup	93.75
Control: passive straining with nylon mesh	1/4 cup	62.5

Table 2: Results from mesh material testing.

Shape

An experiment was conducted with waved, conical, and cylindrical straining surfaces to determine which shape produced the best results (see Figure 10). The experimental procedure was similar to the first experiment; yogurt was measured into the strainer to be tested, and pressure was applied for 5 minutes. Again, the volume of whey removed was recorded for each trial. Based on the results, it was concluded that the cylindrical strainer was the best design (results in Table 3). It was also concluded that the strainer needed to be very well sealed in order to work effectively under pressure.

Figure 10: Clockwise from top left; waved, conical, cylindrical, and passive straining devices.

Trial	yogurt quantity	whey removed	percentage	time	rate	time to 50%
	mL	mL	%	mins	%/min	mins
Wave + nylon mesh	1250	50	4	5	0.8	62.5
Wave alone	yogurt passed through the mesh					
Sealed cylinder-in-cylinder	yogurt passed through the mesh					
Sealed cylinder-in-cylinder with nylon mesh	500	80	16	5	3.2	15.6
	500	160	32	15	2.1	23.4
Sealed cylinder-in-cylinder with more nylon mesh	500	180	36	10	3.6	13.9
Cone	Container wasn't big enough + yogurt had undergone too much mixing and didn't gel together					
Cone with nylon mesh						
Current system (colander + nylon mesh)	500	65	13	5	2.6	19.2

Table 3: Results from strainer shape testing.

3.5 Prototype construction and testing

After determining the material and shape for the strainer, the design team developed a working prototype. For the base material, ABS plastic was chosen instead of PVC or steel because it was inexpensive, it was easy to find the required sizes and fittings, and it was easy to machine. The prototype incorporated the conclusions drawn from the preliminary experiments, such as a cylindrical strainer, a layer of nylon mesh, and a seal with a rubber O-ring. Also, the prototype was designed to be similar in shape to the client's current fermentation tank to facilitate scale-up modeling.

A mathematical model was developed to determine the optimal height of the strainer, such that the strainer would have maximum surface area without allowing the yogurt to overflow, and without the strainer reaching the bottom of the fermentation tank before 50% of the whey was extracted. This algorithm is available in Appendix A.

The conceptual design and physical prototype of the pressurized strainer are shown in Figure 11.

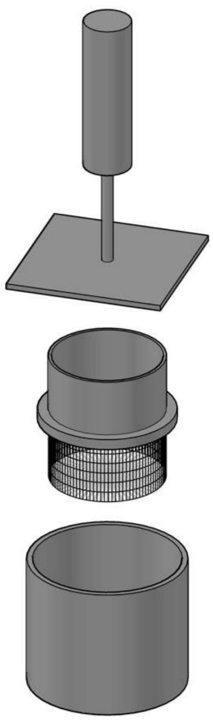


Figure 11: Conceptual design and physical prototype of the pressurized yogurt strainer.

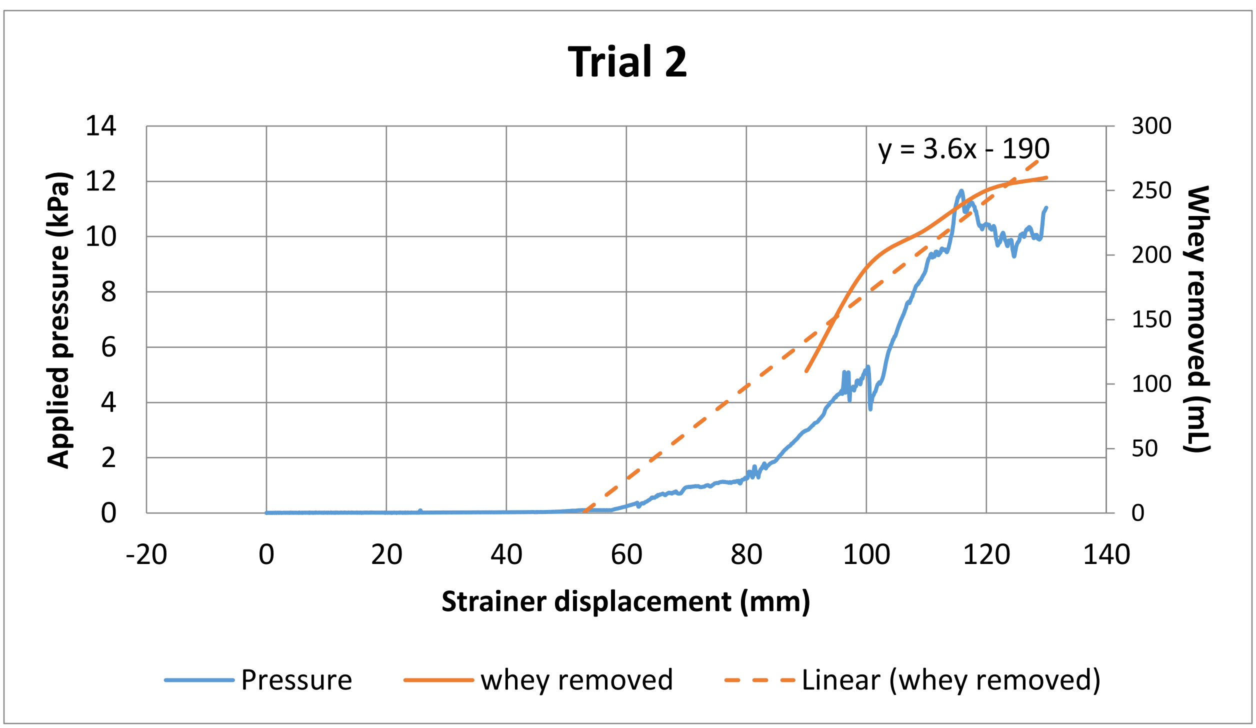
After preliminary testing of the prototype the design team made some modifications to optimize its functionality. The O-ring was removed and the seal of the strainer was filed down to remove approximately 0.5 mm around the edge. This reduced the friction between the strainer and the fermentation container, which allowed the strainer to be operated using less force.

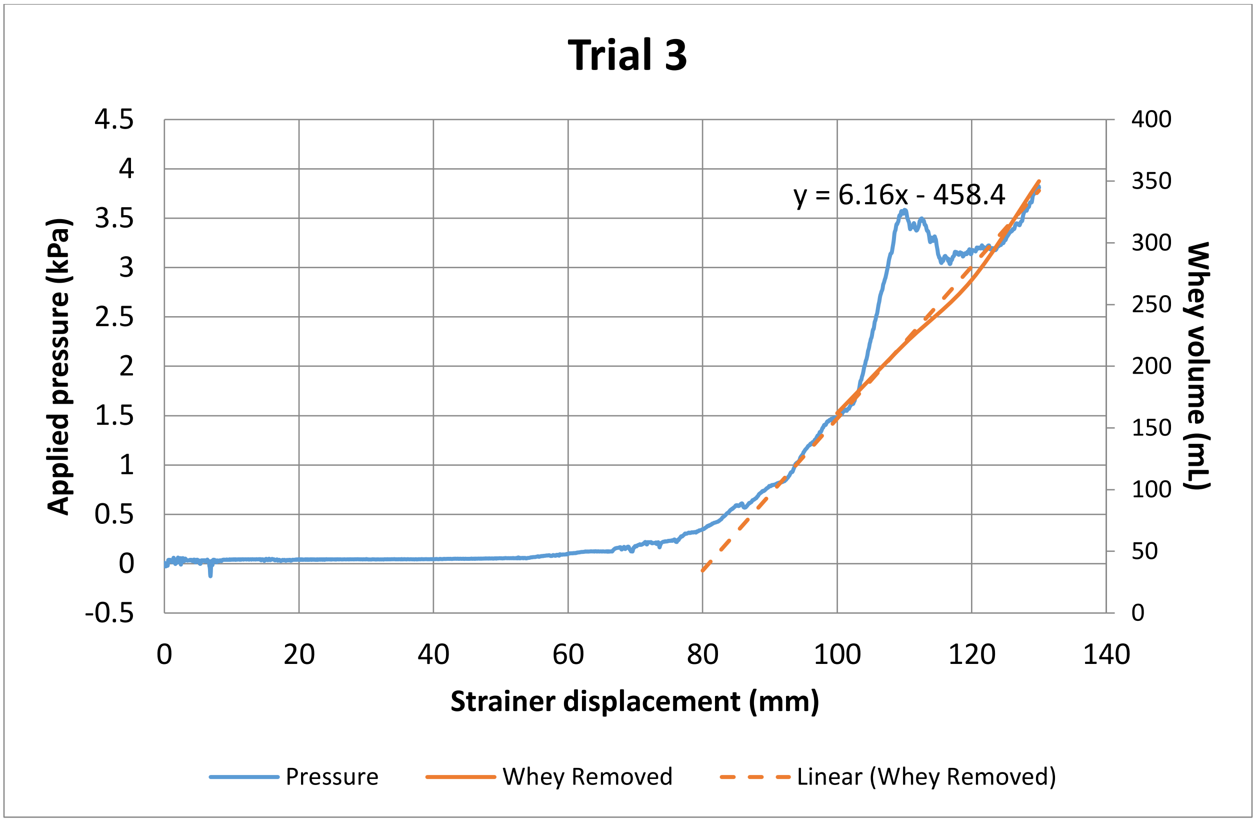
When the prototype was finished the design team conducted an experiment using an Instron 4502 Universal Testing Machine to test the efficacy of the pressurized strainer under different pressures and speeds. The experimental method was as follows: the fermentation container was filled with 600mL of yogurt, and the strainer was pressed into it at a constant speed. The design team tried two speeds (1 cm/min and 0.8 cm/min) and two types of yogurt (commercial and homemade). For each trial the applied force on the strainer was measured by the Instron machine at 0.1-second intervals and the volume of whey removed was measured manually at 1-minute intervals. This method is pictured in Figure 12, and the results are shown in Figures 13-15.

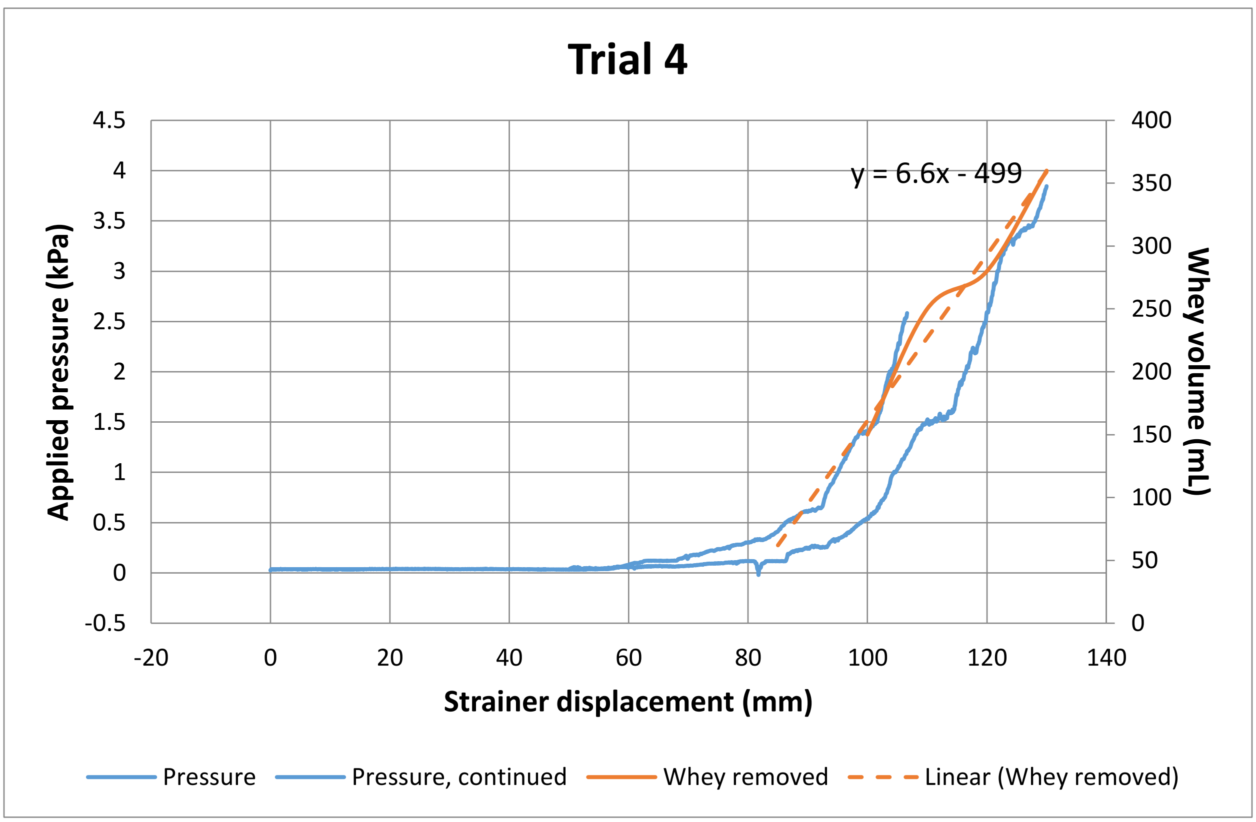
From the results of this experiment, the design team made several conclusions:

1. The applied pressure increased with displacement speed.
2. Applied pressure was limited by the ‘strength’ of the yogurt, which differed between different types of yogurt and increased as more whey was removed.
3. Maximum pressure (before the yogurt stopped separating and began flowing through the mesh) could be found for each type of yogurt. This can be seen in Figures 13 and 14 where the applied force reaches a maximum and then levels out. After this point the yogurt stopped separating and began flowing through the mesh.

Figure 12: The pressurized strainer prototype in the Instron testing machine, and the resulting Greek yogurt and whey.







Figures 13-15: Experimental results from Instron testing.

3.6 Modeling for scale-up

Results from the Instron testing were used to predict the applied force, flow rate and process time for the full-scale pressurized strainer. Specifically, the full-scale strainer dimensions were calculated using the developed algorithm (in Appendix A) and using fermentation tank dimensions of 1.0 m in diameter and 1.0 m in height and a safety factor against overflow of 1.15. The process time was predicted by assuming that the average whey flow rate observed in prototype testing (in mL/cm^2 min) would be constant in the full-scale strainer, and then calculating the time in minutes with the known strainer surface area and volume of whey. Finally, the required applied force was calculated by assuming that the maximum pressure observed in prototype testing would be the same in the full-scale strainer. All calculations and support are listed in Appendix A.

4 Final design specifications

Numerical specifications are listed in Table 4 and the final full-scale design in pictured in Figure 16.

Strainer diameter	0.96 m
Strainer height	0.52 m
Perforated surface area	26540.2 cm^2
Volume of yogurt	350 L
Maximum applied pressure	3.88 kPa
Maximum applied force	10.3 kN
Whey flow rate	0.163 mL/cm^2 min
Total whey flow rate	3.74 L/min
Process time	46.8 min

Table 4: Final design specifications.

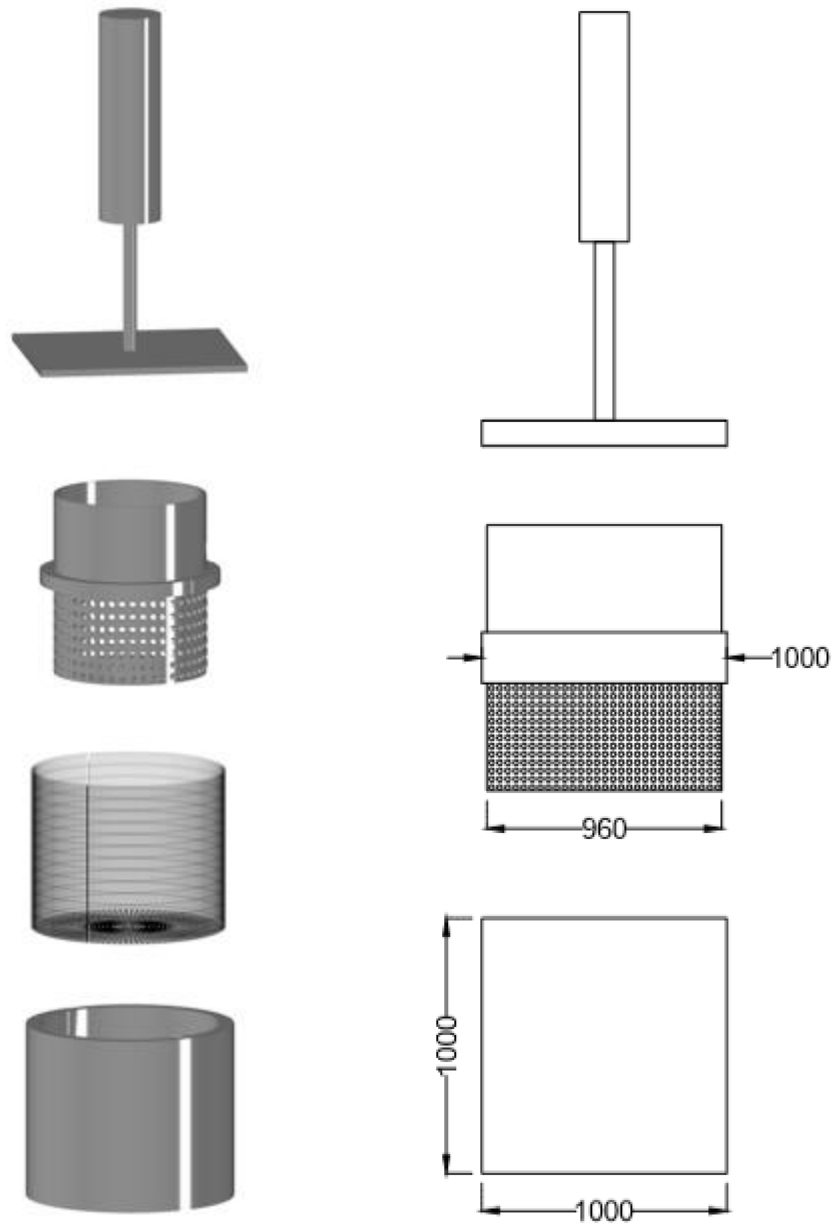


Figure 16: Final full-scale design. All dimensions are in mm.

5 Other considerations

5.1 Safety

Food Safety

To ensure the production of yogurt which is safe for consumption, certain standards for dairy equipment need to be met. Specifically, the design team consulted standards regarding the design and construction of food process equipment set by the Canadian Food Inspection Agency in the Dairy Establishment Inspection Manual (CFIA, 2010) and the NSF/ANSI International Standard for Food Equipment (NSF/ANSI, 2014).

For the design of the yogurt strainer, the following standards were taken into consideration: To facilitate the cleaning, sanitizing and maintenance, all seam and joints will be permanent welds, smooth and resistant to stress. All parts that are not welded or permanently attached will be removable for easy cleaning (i.e. the nylon mesh). The strainer will be constructed from stainless steel and free of imperfections to ensure that no yogurt remains on the strainer or other parts (CFIA, 2010; NSF/ANSI, 2014).

Operator Safety

Operator safety was one of the key criteria and it was carefully considered throughout the design process. For this purpose, the Canada Occupational Health and Safety Regulations were consulted. Specifically, the total weight of the strainer should not exceed what can be safely lifted by two operators, i.e. 46 kg. Furthermore, the employees should be trained on how to safely lift and remove the strainer from the fermentation tank, as well as how to operate the pneumatic pump (Canada Minister of Justice, 2016).

5.2 Economics

The cost for the materials and fabrication of the yogurt strainer was approximated to be less than 5000$. This was estimated by knowing that the fermentation tank and the pneumatic pump already exist at the factory and no additional cost will be added for those components. The payback period for the yogurt strainer was estimated to be 12 days. The overall production of yogurt per month can double and consequently the total monthly income can double as well since more yogurt can be produced in a smaller amount of time. The detailed cost analysis can be seen in Appendix B.

5.3 Optimization

Several potential optimizations have been identified by the design team. Firstly, the stainless steel strainer and the nylon mesh could be replaced by a single layer of fine stainless steel mesh to facilitate cleaning. This would require a more detailed analysis of the strength, possible failure modes, and food safety requirements of a fine stainless steel mesh. Secondly, further testing of Cult's yogurt should be conducted. Yogurt is a fermented product and therefore it is quite different when made with different ingredients and different procedures. During the design process, testing has been conducted with yogurt made by the design team and not with Cult's yogurt. Testing the prototype with Cult's yogurt would help to characterize the behaviour of Cult's yogurt in the pressurized strainer and optimize design specifications like maximum pressure and process time.

6 Conclusion

The purpose of this project was to design and implement an efficient and inexpensive machine to remove whey from yogurt for the client, Cult Yogurt. The procedure involved the identification of criteria, an iterative design and testing process, and a final full-scale design. Through a combination of prototype testing and mathematical modeling, it was shown that the final design meets and exceeds all design criteria. Specifically, the process time of 46.8 min greatly exceeds the design goal of under 3 hours, and the benefits of the pressurized strainer result in a payoff period of only 12 days. Overall the design goal has been achieved, and the design team looks forward to the construction and implementation of the full-scale pressurized yogurt strainer.

Acknowledgements: We thank our client Cult Yogourt, our mentor Dr. G.S.V. Raghavan, and our collaborators Philip Ossowski, Dr. David Titley-Peloquin, Dr. Yvan Gariepy, and Mr. Scott Manktelow for their support throughout this project. We also thank our professors Dr. Viacheslav Adamchuk, Dr. Marie-Josée Dumont and Dr. Mark Lefsrud for their guidance and support.

7 References

Alibaba.com. (2016). Filter press. Retrieved from https://www.alibaba.com/showroom/filter-press-price.html

Brandy, F. (2002). French press coffee maker with assembly to reduce contact of grounds with liquid coffee after termination of steeping period. Patent No: US6422133 B1. Retrieved from https://www.google.ca/patents/US6422133?dq=french+press&hl=en&sa=X&ved=0ahUKEwiCqLG66rrQAhWh44MKHRq-CcgQ6AEIGjAA

Canada Minister of Justice. (2016). Canada Occupational Health and Safety Regulations. Retrieved from http://www.laws-lois.justice.gc.ca/eng/regulations/SOR-86-304/index.html

Canadian Food Inspection Agency. (2016). Reference listing of accepted construction materials, packaging materials and non-food chemical products database. Retrieved from http://www.inspection.gc.ca/active/scripts/fssa/reference/reference.asp?lang=e&cmd=1&cat=20&subcat=0

Canadian Food Inspection Agency. (2016). Dairy Establishment Inspection Manual. Retrieved from http://www.inspection.gc.ca/food/dairy-products/manuals-inspection-procedures/dairy-establishment-inspection-manual/eng/1339533901044/1339534012017

Chandan, R. and O'Rell, K. (2006). Chapter 13: Manufacture of various types of yogurt. In R. Chandan (Ed.), *Manufacturing Yogurt and Fermented Milks*. Ames, IA: Blackwell Publishing.

Conick, H. (2015) US Greek yogurt market to reach $4bn by 2019: Technavio. Retrieved from http://www.dairyreporter.com/Markets/US-Greek-yogurt-market-to-reach-4bn-by-2019-Technavio

Freeman, R. B. (1987). Yogurt separator device. Patent No: US 4680117 A. Retrieved from https://www.google.ca/patents/US4680117?dq=greek+yogurt+strainer&hl=en&sa=X&ved=0ahUKEwiEkrDK6rrQAhUL9IMKHUCtDMoQ6AEIIzAB

GEA Group. (2012). Membrane filtration in the dairy industry. Retrieved from http://www.gea.com/en/binaries/Membrane%20Filtration%20in%20the%20Dairy%20Industry_tcm11-18227.pdf

GEA Group. (2016). Centrifuge nozzle separators for fresh cheese, cream cheese and strained yoghurt. Retrieved from http://www.gea.com/en/products/nozzle-separators-fresh-cheese-cream-cheese-strained-yoghurt.jsp

Grusin, G. (1994). Yogurt cheese making device. Patent No:US 5373779 A. Retrieved from https://www.google.com/patents/US5373779

Karam, M.C., Gaiani, C., Hosri, C., Burgain, J., Scher, J. (2013). Effect of dairy powders fortification on yogurt textural and sensorial properties: a review. *Journal of Dairy Research*, 80(4), 400-409.

NSF International and American National Standards Institute. (2014). NSF/ANSI2-2014: International standard for food equipment. Ann Arbor, MI: NSF International.

Smith, G. (1985). Portable cheese press frame assembly. Patent No: US 4493250 A. Retrieved from https://www.google.ca/patents/US4493250?dq=pneumatic+cheese+press&hl=en&sa=X&ved=0ahUKEwjq_eSP67rQAhVKxoMKHd6UAssQ6AEIIzAB.

Tecnal Products. (2016). Curd filter. Retrieved from http://www.tecnal.fr/en/global.htm

8 Appendices

Appendix A: Calculations

Mathematical Model to Optimize Strainer Dimension

To calculate the optimal height, the following calculation was performed:

$$h = \frac{\pi R^2 H - V}{\pi r^2}$$

Where:
h = Height of the strainer.
H = Height of the fermentation tank.
V = Volume of yogurt (educated estimation*).
R = Radius of fermentation tank.
r = Radius of strainer.

After calculating the height of the strainer, the following constraints had to be fulfilled:

1. Half of the volume needs to be extracted before strainer bottoms out.

$$V > \frac{\pi R^2 H \ (2\pi R^2 - 2\pi r^2)}{2\pi R^2 - \pi r^2}$$

2. The height of the straining portion must be smaller than the height of the fermentation tank:

$$h < H$$

$$h = \frac{\pi R^2 H - V}{\pi r^2} > H$$

3. The volume of the yogurt must be less than the volume of the fermentation tank:

$$V < \pi R^2 H$$

* If criteria were not met with the chosen volume of yogurt, the above procedure was repeated until all criteria were met.

This model was developed with the help of Dr. David Titley -Peloquin.

Calculations for Scaling-Up

To find the maximum pressure required:

$$F_2 = F_1 * \frac{A_2}{A_1}$$

Where:

F_2 = Max force required for the full-scale design
F_1 = Max Force that was recorded from the Instron machine on the model.
A_1 = Area of the perforated part of the full-scale design + top area of the strainer.
A_2 = Area of the perforated part of the model design + top area of the strainer.

To calculate the rate of removal of whey:

$$q_2 = q_1 * \frac{A_2}{A_1}$$

Where:

q_2 = Max rate of whey removed in full-scale design.
q_1 = Max rate of whey removed during testing.
A_1 = Area of the perforated part of the full-scale design.
A_2 = Area of the perforated part of the model design.

To calculate the process time:

$$t = \frac{V}{q_2}$$

Where:

t = process time
V= Volume of why that needs to be extracted.
q_2 = Rate of whey removed in full-scale design.

This model was developed with the help of Dr. Vijaya Raghavan.

Appendix B: Cost analysis

COST OF STRAINING SYSTEM				
Component	**Description**	**Quantity**	**Cost Per Unit**	**Total Cost (CAD $)**
Pneumatic Press				0
Perforated Strainer	24"x 24" Stainless Steel Perforated Sheet	5	73.6	368
	48"x 48" Stainless Steel Perforated Sheet	1	211.97	211.97
	24"x 48" Stainless Steel Sheet	3	77.48	232.44
Mesh (Fabrique)				260
Stainless Steel Circular Fitting				72
Fermentation Container				0
Fabrication Procedure	Food Grade Welding			3000
	Polishing			
	Cutting and Molding			
Total				4144.41

CURRENT COST ANALYSIS (MONTHLY)		
Profit	10370.4	(CAD $)

COST ANALYSIS USING PRESSURIZED STRAINER (MONTHLY)		
Profit	20740.8	(CAD $)
Profit Increase	10370.4	(CAD $)

Payback Period		
Initial Investment	4144.41	(CAD $)
Monthly Profit Increase	10370.4	(CAD $)
Payback Period	**12**	**Days**

All estimations for the price of materials were based on the McMaster-Carr website.