Reducing Cycle Time in Frozen Gel-Bag Production

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Reducing Cycle Time in Frozen Gel-Bag Production

**Problem Statement**
PurFoods estimates they will use two million gel-bags this year in their packaged meal delivery boxes. Currently, cycle time to freeze gel-bags is about 24 hours. PurFoods would like to reduce this time by at least 25%, opening up valuable inventory space and providing flexibility in meeting market demands.

**Disciplines**
Bioresource and Agricultural Engineering | Industrial Technology

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Recommended Citation

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1 PROBLEM STATEMENT

PurFoods estimates they will use two million gel-bags this year in their packaged meal delivery boxes. Currently, cycle time to freeze gel-bags is about 24 hours. PurFoods would like to reduce this time by at least 25%, opening up valuable inventory space and providing flexibility in meeting market demands.

Problem Statement

- PurFoods is a nationwide home-delivered nutrition solution company whose goal is to provide healthy and convenient meals to its customers. They produce a wide variety of healthy frozen meal packages for their clients. PurFood’s products are shipped frozen right to the customer’s door. Their customers are generally seniors and patients who have trouble preparing nutritious meals. PurFoods is currently one of the top competitors in the healthy frozen food market. The
corporate office and one of their shipping facilities are based out of Ankeny, Ia. The kitchen where all of the food is cooked and packaged is based out of Grinnell, Ia. They also have shipping facilities in Ohio and Las Vegas.

- Currently, these frozen packs take an average of 24 hours to freeze completely. To keep up with demand, they have thousands of frozen packs sitting on shelves frozen at all times. With meals in high demand, PurFoods wants to reduce the amount of space that the frozen gel packs are taking up. To do this they need to reduce the freeze time of the gel-bags to free up space.

- The bags are produced in their facility and consist of silicon and room temperature water.
- PurFoods’ other shipping facilities will benefit from this solution as well. All of their facilities are using an ample amount of space to store frozen gel-bags.

**Business Case Statement**

A. **What** - PurFoods is looking for a way to reduce the freeze time of their freezer bags.

B. **How** - As PurFoods continues to grow and expand, change to the process is necessary to keep up with the high demand for freezer bags.

C. **When & Where** - The onsite testing will occur in Ankeny at PurFoods LLC, The team meetings will occur at Iowa State University in Ames.

D. **Why** - Addressing this problem will allow for cost savings through saving valuable space.

E. **Who** - Our contacts, have shown us through their testing and research of the problem that this problem has been thought about in great detail and is important to PurFoods.

## 2 Goal Statement

A. Reduce gel bag freezing time by 25%. Reduce inventory costs associated with storing gel bags. Reduce footprint required to store in cooler

B. We will measure our improvement by comparing current freeze times per bag (24hr standard) to our future freeze time per bag. This data will be analyzed as a percent change in time.

C. **Main Objective(s) and Specific Parameters**
   a. The main objective is to reduce the time that the freezer bags have to spend in the freezer to increase the output of freezer bags and decrease cycle time.
   b. **Specific parameters include:**
      i. Gel bag size cannot be changed
      ii. Dimensions of shipping box cannot be altered
      iii. The solution must be food safe
      iv. Production must stay the same

D. **Rationale**
   a. The freeze cycle time will be reduced by at least 25% allowing creating the less of a need for gel packs on hand.
   b. A portion of current gel pack storage will be better utilized for inventory storage.

## 3 Project Plan/Outline

- **Methods/Approach**
- Reference Materials
  - Testing data and freeze times for the bags used in the existing freezer setup.
  - Production output numbers from new bagging machine.
  - Future prospected gel bag use number given by PurFoods.
  - The main reference materials that we used were from Gary Long and Josh Gondek who are our contacts from PurFoods. They provided a large amount of background information and assistance on this project
  - Dr. Koziel was our faculty mentor and he guided us through the project with his specialty

- Data collection
  - Gathering data will be done with the use of temperature sensors that log data to an Excel spreadsheet.

- Skills
  - HVAC and ventilation skills learned in TSM 210 will potentially be utilized.
  - Industrial freezing technologies available on campus will potentially be utilized.
  - Material handling
  - Facility layout planning

- Proposed Solutions
  - Adding salt to the gel bag mixture
  - Using pre-chilled water rather than room temperature
  - Using deionized water rather than tap water
  - Storing the bags on pre-chilled metal or plastic racks
  - Increasing air flow around the gel bags in the warehouse

- Solutions were created through research by PurFoods and the Capstone team
- PurFoods has given a desired freeze reduction time but currently does not have a cost metric associated with the project.
- The proposed solutions will be evaluated by the percent change in freeze time.
  Solutions will be ruled out if the minimum 25% reduction time is not met.
- The success of this project is defined as meeting a freeze reduction time of 25% or more. A higher reduction will be deemed more successful.
- Currently proposed solutions are consistent with the objectives and scope of the project provided by PurFoods
- PurFoods feedback and data from the proposed solutions will prove very helpful in the success of this project.

- Organization:
  - Meetings were held weekly in which workload was distributed
  - Major Milestones:
    - Created a fan layout that minimized freezing time required for the gel bags
    - Defined issues within material handling that need to be addressed

- Results/Deliverables
  - A solution that reduces the freezing time by at least 25% and providing cost analysis
  - The project was not fully implemented, but the plan for implementation is set in place.
  - Additional recommendations for our client based on this project or future ideas
  - A material handling plan will be set in place after the fan installation is complete.
If the project is approved to be implemented it would take place after the new bagging machine is installed, starting as early as the summer of 2018

4 Broader Opportunity Statement

A. Our project has an appeal in the food industry and can be easily understood.
B. Our project affords process improvement and helps provide frozen food efficiently.
C. This project will be adapted by another Purfoods plant.
D. This project could be adapted by other companies that work with products that involve minimizing freeze times.
E. Minimizing freeze times minimizes waiting times for customers and meets the growing demand for time-critical production.
F. Freezers are costly to operate so many companies would be interested in a system that effectively reduces freezing costs and would be willing to pay to offset long-term costs.

5 Project Scope

A. The boundaries of this project lie between the manufacturing of the gel bag and until the bags are removed from the freezer. The project scope was defined by the sponsor and will not require changes.
B. The project is overseen by PurFoods Director of Fulfilment, Josh Gondek.
C. This project applies to the warehouse and shipping aspect of the company.

6 Graphical Abstract

Phase 1: Proposed Solutions Testing

Phase 2: Larger Scale Airflow and Chilled Water Testing

Phase 3: Fan Speed/Performance Testing

Phase 4: Various Layout Testing
7 REFERENCES


Joseph R. Vanstrom and Jacek A. Koziel. TSM 416 Technology Capstone Project, April 13, 2018


The main reference materials that we used were from Gary Long and Josh Gondek who are our contacts from Purefood. They provided a large amount of background information and assistance on this project.
Appendixes

1. Initial Freeze times
   a. Alternative Methods
   b. Alternative Method Initial Testing
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11. Material Flow Original
12. Material Flow Change With Fans
13. Additional Ideas for the Future
    a. Storage changes
    b. Freeze Tunnel
1. Initial Freeze Times

<table>
<thead>
<tr>
<th>Minimum Freeze Time</th>
<th>4.25 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Freeze Time</td>
<td>30.5 hours</td>
</tr>
<tr>
<td>Average Freeze Time</td>
<td>16.66 hours</td>
</tr>
</tbody>
</table>

Times above our from the original data given to us. Time was estimated to be 24 hours of freeze time. We saw an average closer to 17 hours, but there was a wide range of times. Most of the data points were around the 16 to 24-hour mark with outliers going as low as 4.25 hours and as high as 30.5 hours.

1A. Alternative Methods

1. Airflow increased through fan usage
2. Chilled water down to about 35 degrees Fahrenheit
3. Metal racks for the gel-bags to sit on
4. Deionized Water
5. Adding salt to the gel-bag mixtures
6. Freeze tunnels

The solutions will be analyzed and measured using temperature sensors placed on the gel packs. Each solution will be evaluated by how much faster or slower the gel pack freezes completely. The data will be compiled into an excel spreadsheet for further analysis.

1B. Alternative Method Initial Testing

All solutions except for the freeze tunnel were tested. Sensors were only placed on the top bags due to the number of sensors available. From this data, we saw the most promise in increased airflow and chilling the water beforehand. Salt also appeared to work, but it would have negative effects on the

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thaw time. More testing is needed to see the increased air flow and water temp on a larger scale more controlled test. Freeze tunnels were not tested due to the high cost of buying one and lack of availability to test one.

The metrics that will be used to evaluate the solutions primarily depend on how much faster the bags freeze although cost may play a factor if the solutions produce similar outcomes.

2. Larger Scale Airflow and Chilled Water Tests

2A. Setup

Two pallets were used for this test along with four sensors per pallet spread out across the various levels of gel-bags to get accurate readings at all parts of the pallet. The first pallet’s gel-bag had been prechilled in the 35-degree Fahrenheit freezer. The second pallet was room temperature water gel-bags straight from the bagging machine. Both pallets were then positioned with one fan in front and one fan above them.

2B. Data
### 2C. Results

From the tests conducted above, we could see that the chilled water had no benefit, actually making the freeze time take slightly longer. With just the fans and room temperature water we were able to drop the freeze time to an average of 6.04 hours. From these results figuring out which fan orientation, size, and layout, is our best option. Running copper coils to chill water before it is bagged and froze does not appear to be worth the return.

### 3. Why Fans are Effective

#### 3A. Convective heat transfer

In this project, we are dealing with convective heat transfer. In convective heat transfer, both gases and liquids are treated as fluids. This means air has a convection current too, where heat is transferred by this fluid. Warmer molecules move faster and upwards, as the cooler denser air sinks. As cold air sinks, it compresses and warms, as warm air rises, it expands and cools.

#### 3B. Boundary-Layer heat transfer

In this project we see pockets of warm stagnant air forming between the gel-bags. These air pockets create a resistance layer around the bag, making it harder for the bag to cool down and freeze. Fans work by reducing this resistance layer and lowering the heat transfer coefficient.

The heat transfer coefficient used by convective heat transfer depends on the speed at which air is moved over the surface of an object. As this speed increases, we see a smaller coefficient of heat transfer allowing the bags to freeze quicker. The type of material being heated or cooled does not play a
large role in this form of heat transfer, rather it is affected most by the velocity at which the fluid, in this case, air is traveling. When there is a temperature difference between the fluid and an object a boundary or resistance layer begins to form. This thickness is dependent upon the equation Reynolds number (Re=V*r*I/mu)

4. Fan Size vs Effectiveness

4A. Fan Speeds

We wanted to determine the speed of the fan played much of a role in how fast the gel-bags were freezing. The next test we ran involved two pallets with the same sensor setup. One pallet used a 30” 8,400 Cfm fan from Global Industries, while the other pallet would have a 30” 7,250 Cfm from Dayton. Both fans would be mounted and positioned above the pallets.

4B. Fan Costs

30” 7,250 Cfm from Dayton

$182.96 per fan no bulk pricing

30” 8,400 Cfm fan from Global Industries

$185 a piece bulk pricing
4C. Freeze Times

From the test conducted we could see that the 30” 8,400 Cfm fan from Global Industries froze the gel-bags in an average time of 9.63 hours, while the 30” 7,250 CFM fan from Dayton froze in about 11.07 hours. The Dayton fan was also used in the testing before this so we could show that there is a significant amount of value in having a fan above and behind the stack in terms of reducing freeze time. From this tests and the prices being similar due to bulk buying of the Global Industries fan we can determine that the larger 8,400 Cfm fan is better for the project and more cost-effective.

5. Testing of Various Layouts

5A. Single Fan Above

The layout on the right show shows three spaces which can contain two pallets per space. The racks go 5 spaces high. Based on this layout and the bag producing capabilities of the new machine we will need 21 of these spaces. One fan would be used per space so in total we would have 21 fans.

Max capacity of machine 4800 / bags per pallet 234 = # of spaces

# of spaces = 20.51 or 21 spaces
5B. Fan Above and Behind

In this layout shown below, we will have a two fan setup per pallet or four fans per space. This would give us a total of 42 fans for the 21 spaces. However, with the extra fans, we will see an additional increase in freeze time reduction.

![Fan Layout](image)

5C. Single Fan Below Shooting Up

This option was not tested, but we believe it may have a positive effect on the freeze time and is worth trying. It would involve one fan per pallet or two per space shooting up on the pallets instead of down.
5D. Data

Data is still being collected on these tests, but from our previous testing, we believe the two fan system per pallet is the route to go. This will have the highest positive effect on freeze time and return on investment.

6. Cold Environment Concerns

6A. Safety

Safety is a concern for workers working in a negative 10-degree Fahrenheit freezer. However, the airflow increase is in a small controlled environment. The fans can be turned off easily whenever they are needed to be off. Because of these factors, the PPE that is already in place for this freezer is sufficient for dealing with the new system.

6B. Labor costs

Working in the cold freezer is going to cost a premium. For all labor calculations, we are assuming a premium of 30% of multiplying labor by 1.3 to account for working in this environment.

7. Inventory Space Costs

7A. Pallet Costs

PurFoods estimates that the dollar amount for saving one space containing two pallets is $24.95 a month + $5.00 in labor to move the pallets. This totals to $30.00

$30.00 * 12 months = $360 per year saved per space
7B. Pallets Saved

With future growth PurFoods estimates they will expand to 150 spaces. With the reduction in freeze time, this could likely be cut in half down to 75 spaces. This would include fan positions plus safety stock as gel-bags in storage. More pallets can likely be saved depending on the time of the year and what projections or demand is at that time. This will be for PurFoods to adjust. During peak times likely all fan positions will be operating, but during slow times some of these spots can be turned into storage and a total number of pallet spaces can be lowered saving additional money in that time.

8. Protrusions on Top of Gel-Bags During Fan Tests

During the tests, Protrusions were noticed on the top layer of gel-bags closest to the fan. Our group believes this is likely due to the proximity of the fan at those gel-bags with nothing in between them. The fan is hitting these gel-bags at full blast, so they are freezing extremely fast, but they are not usable. Adding an empty bread crate above these racks will restrict the airflow to these bags slightly so it gets a more even freeze like the crates below it. This top layer of bags will take longer to freeze but will be usable and more in line with the freeze time of the rest of the stack.

9. Cost Analysis

Fan cost - $185 per fan * 2 fans per pallet position * 21 pallet positions = $7,770

Electricity cost - $7,919 Per year

- 24 hours/365 days per year
- Iowa average electricity cost $0.105 per kWh
- Fans are 205 Watts

This electricity cost is likely a very high estimate because these fans will not be running 24/7 most of the time, however, for calculation simplicity, we gave the 24/7 cost.

Labor - Currently getting quotes

Total Cost - $7,770 + $7,919 + (Labor * 1.3 (Premium cost for cold conditions))

10. Return on Investment

$360/per year for every pallet position saved

- 75 pallet positions saved * $360 = $27,000 per year

First year cost $7,700 + $7,919 + (Labor * 1.3)
First year savings $27,000 - $7,700 (fans) + $7919 (electricity) + (Labor * 1.3)

Saving after $27,000 - $7,919 - maintenance costs ($100 + Labor)

More positions may be saved at various time raising the cost savings. Maintenance is calculated based on labor, plus a designated amount for parts. Fan life is estimated at 102,000 hours or about 22 years when ran 24/7 however due to the conditions the fans will be in we think this life could be more safely estimated at about 10 years.

11. Material Flow Original

As we started the project gel-bags were being made at the bagging machine and then brought into storage to freeze. After at least 24 hours the bags were brought out of storage fully frozen and brought onto the packaging floor to be packaged with meals and shipped out. Bags were likely sitting much longer then the freeze time and a large amount of safety stock was built up for when demand was higher, problems in freezing, and due to machine reliability. This system was a type of pull system.

12. Material Flow with Fans

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Our proposed solution would change this original flow. The bags would still be produced at the bagging machine. They would then move to fan racks where they would be frozen over the 6 to 10 hour cycle time. Once they are frozen they would then be moved to storage, and another batch would be put under the fans. The fans would be set up to hold 4914 gel-bags which is slightly more than the new bagging machine is capable of producing in one shift. When the max production is not needed fans could be turned off and can be converted to regular storage saving electricity costs. It would be up to PurFoods on how much additional storage they would want and this is likely to change at various times of the year based on weather, and demand projections. We recommend keeping on hand enough storage for the gel-bag fan positions plus another cycle or two. Due to comfortability with machine reliability PurFoods may want to keep more safety stock in this, but eventual change to more of a pull system would be beneficial in saving money.

13. Additional Ideas for the Future

13A. Changes in Storage

Storing the safety stock more efficiently is another way money can be saved. Eliminating this stock in a pull system is one option, but if PurFoods wants to keep all or some of this there are ways we can save pallet space once the gel-bags have been frozen. We believe some time of Container storage system will be more efficient than the current bread crate towers. These bread crate towers are great in allowing air to flow more freely between the bags allowing for a faster freeze time, however once they are frozen this extra space works against the goal. The bags are not going to unfreeze once they are frozen so the bread racks become unnecessary. Designing a new storage system as simple as a large tub would allow a higher amount of gel bags to be stored in a small space. This new system would have to still be easily moveable by an operator and ergonomic for workers to pull gel-bags out of.

13B. Freeze Tunnels

Our group mentioned freeze tunnels as a proposed solution at the beginning of the project, however we did not believe it was a viable option with the current setup, but it could be with some changes. A freeze tunnel would freeze the gel-bags instantly and allow for JIT production, but it has a various high start-up cost for the machine, liquid nitrogen, and a waste removal system. It would also require skilled labor to work this machine. With the current push system it would not save enough money to make sense, and the machine reliability would still be a huge concern. If you went completely to a pull system, it may then start to become a more viable option if you could find a way to limit the reliability concerns.