

THE EFFECT OF FREEZING ON CRANBERRY PROPERTIES

A Major Qualifying Project Report:

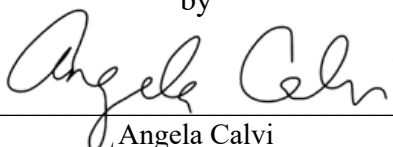
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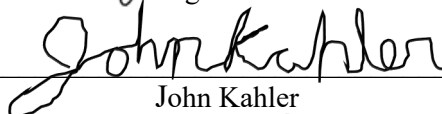
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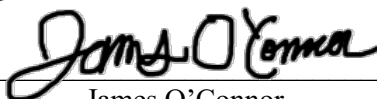
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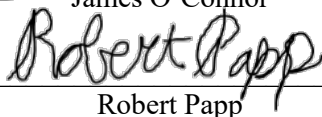
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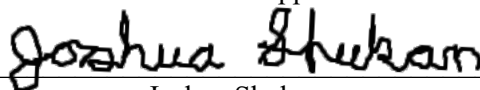
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Abstract

The purpose of this project was to investigate the relationship between freezing and four physical properties of cranberries. Berries underwent three different freezing protocols of variable duration and temperature. Tests were conducted to determine changes in the physical properties of cranberries: infusibility, expressibility, physical strength, and cell shape. The infusibility of cranberries increased with exposure to all freezing protocols. No expression was observed for any freezing protocol. Force testing was inconclusive due to machine error. The shape of cranberry cells became longer with initial freezing and rounder with increasing exposure to freezing protocols. Further investigation and replication are required to determine correlations between freezing and physical properties.

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Table of Contents

Abstract.....	2
Acknowledgements.....	3
Table of Contents.....	4
Table of Tables.....	6
Table of Figures.....	7
Introduction.....	8
Background.....	9
<i>General freezing of food</i>	9
<i>The effect of freezing on plant cells</i>	9
Methodology.....	10
Freezing.....	10
<i>Constant Temperature</i>	10
<i>Cyclic</i>	10
<i>Long Freeze</i>	11
Testing.....	12
<i>Brix Testing</i>	12
<i>Infusion</i>	12
<i>Expression</i>	13
<i>Instron Testing</i>	13
<i>Scanning Electron Microscopy</i>	13
Results and Discussion.....	15
Infusion.....	15
Expression.....	16
Instron Testing.....	17
Scanning Electron Microscopy.....	18

<i>Visual Comparison of Representational Scans</i>	18
<i>Comparison of Aspect Ratio</i>	22
<i>Comparison of Aspect Ratio to Infusion Results</i>	25
<i>Comparison of Aspect Ratio to Instron and Expression</i>	26
Recommendations.....	28
References.....	30
Appendices.....	31
Appendix A: Cyclic Temperature versus Time – Full Length	32
Appendix B: Instron Voltage Data versus Time.....	33
Appendix C: SEM Micrographs	35
<i>Appendix C-1: Constant Temperature Micrographs</i>	35
<i>Appendix C-2: Cyclic Micrographs</i>	39
<i>Appendix C-3: Long Freeze Micrographs</i>	43
Appendix D: The Impact of Free Trade Agreements on The Ocean Spray Cooperative	46

Table of Tables

Table 1: Infusion Results	15
Table 2: Slopes and Intercepts of Brix by Freezing Protocol	16
Table 3: Summarized table of cellular aspect ratios	24

Table of Figures

Figure 1: Constant Temperature versus Time and Theoretical Constant Temperature freezing protocol	10
Figure 2: Cyclic Temperature versus Time and Theoretical Cyclic Temperature versus Time...	11
Figure 3: Long Freeze Temperature versus Time and Theoretical “Long Freeze” Temperature versus Time	11
Figure 4: Long Freeze Temperature versus Time, 0 °F Constant Portion	12
Figure 5: Brix percentage versus Time	15
Figure 6: Representative scans of a never-frozen cranberry.....	18
Figure 7: Representative scans of cranberries frozen with the Constant Temperature protocol ..	18
Figure 8: Close up of Constant Temperature 47 and Constant Temperature 56	19
Figure 9: Representative images of cranberries frozen with Cyclic Protocol	19
Figure 10: Close up of Cyclic 7 and 21	20
Figure 11: Representative images of cranberries frozen with the Long Freeze Protocol.....	20
Figure 12: Close up of Long Freeze 75 and 110.....	21
Figure 13: The relative frequency of the aspect ratio of never-frozen cranberries.....	22
Figure 14: The relative frequency of the aspect ratio of Constant Temperature cranberries	22
Figure 15: The relative frequency of the aspect ratio of Cyclic cranberries.....	23
Figure 16: The relative frequency of the aspect ratio of Long Freeze cranberries	24
Figure 17: Comparison of mass percent sugar in cranberries after infusion to aspect ratio	25

Introduction

Ocean Spray is an agricultural cooperative comprised of over 700 grower families throughout the Americas. The cooperative produces a myriad of cranberry-based products, including but not limited to sweetened dried cranberries (SDCs), known to most as the Craisin[®]. The first step in the SDC production process is freezing. This project was carried out in conjunction with Ocean Spray in order to determine how different freezing protocols affect the physical properties of the berries ready for Craisin[®] production.

Three freezing protocols were investigated over the course of the project: “Constant Temperature”, “Cyclic” and “Long Freeze”. The Constant Temperature protocol froze berries at a sustained low temperature for several weeks, while berries undergoing the Cyclic protocol oscillated between being stored at low temperature to room temperature every 24 hours. The Long Freeze protocol stored the berries at their freezing point for one month, and then decreased the temperature every other day until reaching the final temperature. These protocols were guided by last year’s team, who achieved uniform freezing throughout the freezer provided by Ocean Spray.

This project aimed to investigate four physical properties that may be altered by differing freezing protocols: physical strength, cellular shape, infusibility, and expressibility. Physical strength was tested using an Instron machine to physically depress thawed cranberries to a maximum depth and to develop a force versus displacement relationship. A scanning electron microscope was used to image cross-sections of thawed berries, and the images in turn were used to explore the relationship between freezing protocol, time, and cell aspect ratio. Thawed berries were infused with a sugar syrup solution in a controlled manner and then the sugar mass percentage was tested to determine if different freezing protocols or freezing duration had any effect on how much syrup the berries could absorb in a controlled amount of time. Expression, which is a term coined by Ocean Spray to characterize a berry’s loss of syrup after the infusion process, was tested by placing weights on berries that had been infused and dried to mimic the weight of other bags of product; the mass gained by an absorptive pad was determined to be the mass of syrup expressed.

By testing these four physical properties in this manner, the project sought to determine how the properties varied with freezing, if the testing methods were valid, and how Ocean Spray could potentially consider changing its process to create the best product possible, as defined for this project by a high infusibility with a low expressibility.

Background

General freezing of food

Freezing of food is done to ensure the freshness of the product over extended periods of time. Foods also have a longer shelf life while frozen than while unfrozen. Freezing also inhibits microorganism growth. Many microorganisms, such as yeast, bacteria, and molds, are inactive at temperatures at or below 0 °F (FSIS-USDA, 2013). By freezing water into a solid, microorganisms undergo dehydration. The lack of liquid water slows the growth of microorganisms, leading to increased shelf lives of frozen goods (ASHRAE, 1997). Ocean Spray implements freezing to maintain a supply of cranberries throughout the year after the harvesting season has passed.

The effect of freezing on plant cells

When plant cells are frozen at temperatures between 0 °C and –30 °C they undergo a slow freeze; in this temperature range, water undergoes nucleation slowly and predictably. Ice crystals will form in the intercellular spaces first, where there is less resistance to the diffusion of water. This lowers the concentration of liquid water outside the cell, which in turn osmotically draws water from the cell into the intercellular space, dehydrating the plant cell. The now large volume of water outside the cell also freezes, physically separating cells and causing irreversible physical damage (Wojtas et al., 1999). Slow freezing in this temperature range also ruptures the cell membranes (Hung, Thompson, 1989).

When plant cells are frozen at temperatures lower than –30 °C they undergo a fast freeze. As opposed to slow freezing where water nucleates in intercellular spaces, in a fast freeze water throughout the plant cells will nucleate. This leads to small ice crystals dispersed both inside and outside the plant cells (Petzold, 2009). Free water within the plant cells then freezes within the cell membrane instead of in the intercellular spaces (Wojtas et al. 1999). It has been observed that this type of freezing does not pierce cell membranes (Hung, Thompson, 1989).

Current Ocean Spray procedure calls for cranberries to be frozen in order to preserve the harvest for year-round production. Ocean Spray also uses this freezing to disrupt the cranberries in such a way that they become ready for SDC production. In order to produce SDCs, the cranberries need to undergo sugar syrup infusion, which Ocean Spray believes to be inhibited by undisrupted cranberry cells. Disrupting the cells in this way is hypothesized to rupture the cell membranes and allow faster infusion of the sugar syrup. However, this also allows for syrup to leak back out of the SDC after infusion, leading to expression.

Methodology

Freezing

Three freezing protocols (Constant Temperature, Cyclic, and Long Freeze) were investigated to determine the effect of freezing on syrup infusibility and expressibility as well as the cellular shape and strength of the berry. Temperature data was collected using thermocouples placed randomly inside bags of Ocean Spray cranberries stacked into the freezer.

Throughout this paper, cranberries from a specific sample of a freezing protocol will be referred to by that freezing protocol, followed by the number of days the berries followed that protocol; e.g. “Long Freeze 75” refers to berries that were sampled after 75 days in the Long Freeze protocol.

Constant Temperature

For the Constant Temperature method, cranberries were placed in a freezer at $-18\text{ }^{\circ}\text{C}$ ($0\text{ }^{\circ}\text{F}$). The goal of this method was to determine how the duration of freezing affects the cranberries. To assess this, berries were removed from the freezer after 33 days, 40 days, 45 days, 47 days, 49 days, and 56 days. Figure 1 shows the representative data of the freezing protocol and the theoretical freezing profile that the team expected to observe for the Constant Temperature method.

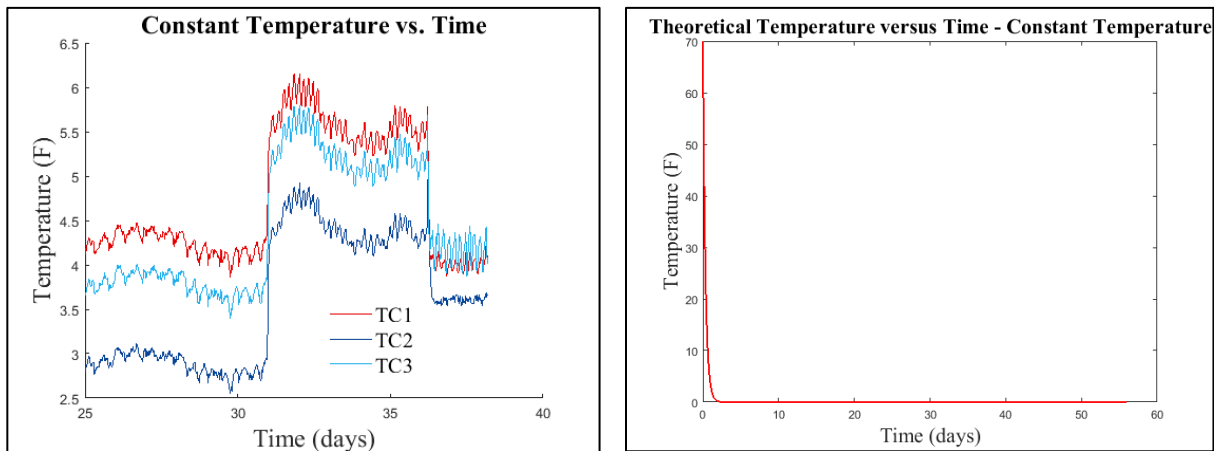


Figure 1: Representative thermocouple data of Constant Temperature versus time (left), Theoretical Constant Temperature freezing protocol (right). The temperature of the representative data begins at about $4\text{ }^{\circ}\text{F}$ and at 25 days. Due to data collection error, the temperature profile for the initial freezing was not available.

Cyclic

The Cyclic freezing method was designed to induce more cell disruption in the berries than the Constant Temperature and Long Freeze tests. This increased cell disruption was hypothesized to be the result of the water in the cells melting and re-nuclearizing in the intercellular space, driving the osmotic pressure that disrupts the cell membranes. Cranberries were placed in the freezer at $0\text{ }^{\circ}\text{F}$. Every 24 hours, the cranberries were removed from the freezer and placed at room temperature or replaced into the freezer. Cranberries were removed for testing after 21

days. Figure 2 below is the representative data of the freezing protocol and the theoretical protocol the team expected to observe for the Cyclic freezing method.

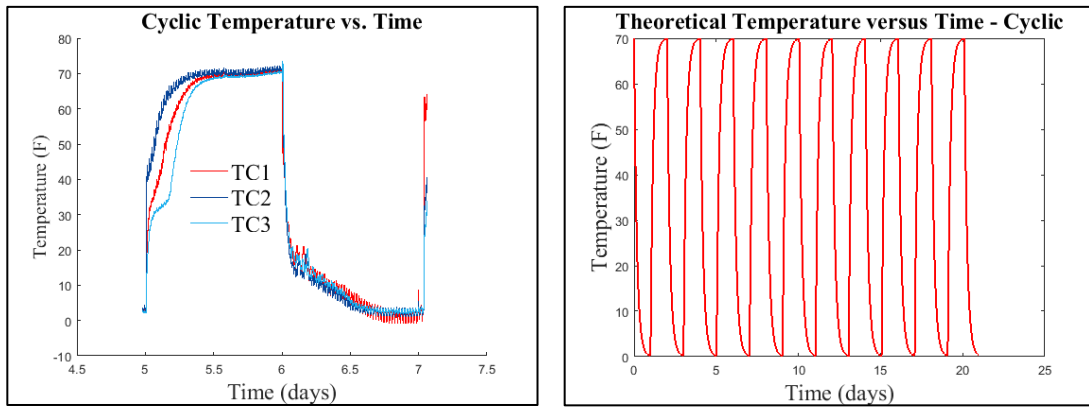


Figure 2: Representative two-day Cyclic Temperature versus Time (left), Theoretical Cyclic Temperature versus Time (right)

Long Freeze

The Long Freeze method was designed to observe how a period of gradual freezing affects the berries. The berries were initially placed in the freezer at a temperature of $-1\text{ }^{\circ}\text{C}$ ($30\text{ }^{\circ}\text{F}$) for 30 days, after which the temperature was progressively decreased by $1\text{ }^{\circ}\text{C}$ every two days until the freezer reached a temperature of $-18\text{ }^{\circ}\text{C}$ ($0\text{ }^{\circ}\text{F}$). Once at the final temperature, the freezer remained at that temperature for the remainder of the test. Berries were removed for testing after 75 days and 110 days. Figure 3 displays the temperature profile of the Long Freeze berries from day 34. It agrees well with our theoretical freezing protocol in Figure 4.

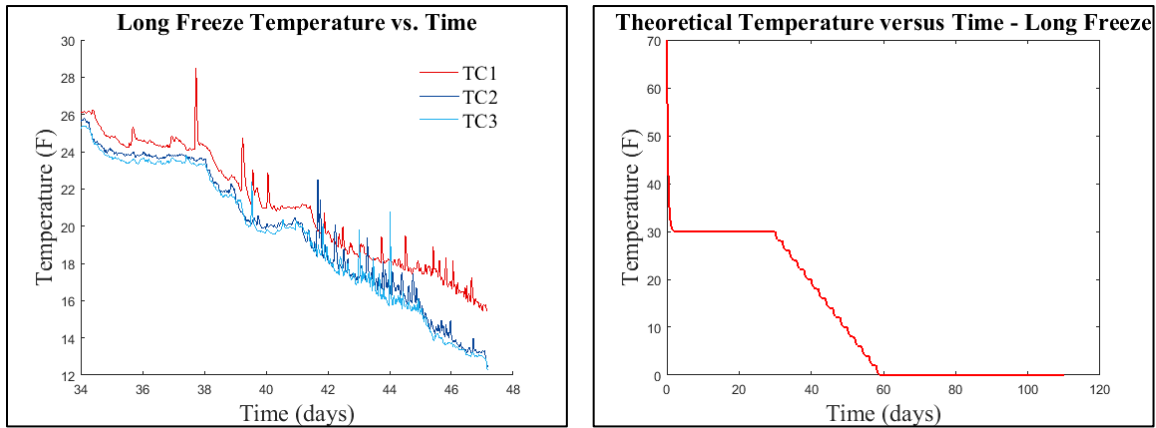


Figure 3: Long Freeze Temperature versus Time, Decreasing Portion (left), Theoretical Long Freeze Temperature versus Time (right). The temperature of the representative data begins at about $26\text{ }^{\circ}\text{F}$ and at 0 days. Due to data collection error, we do not have the temperature profile for the initial freezing.

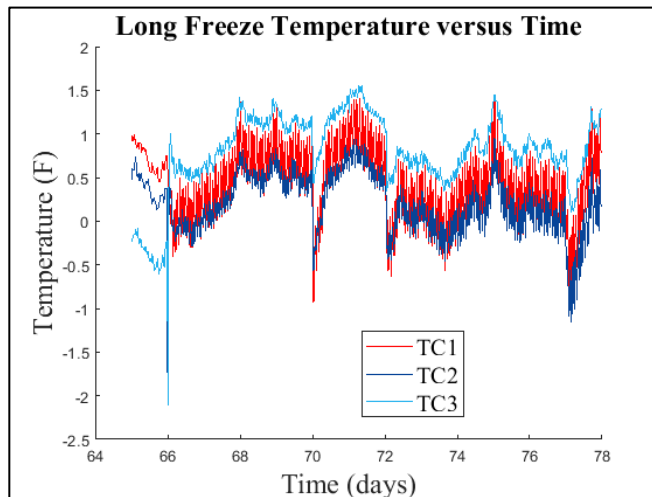


Figure 4: Long Freeze Temperature versus Time, 0 °F Constant Portion. The scatter is likely due to electrical error.

Testing

To measure the effect of freezing protocols on the physical properties of cranberries, experimental tests were performed. The tests below can briefly be summarized by the property they measure. The “Brix” test measures sugar content, the “Infusion” test measures the rate at which sugar entered the cranberries, the “Expression” test measures the rate at which syrup exits sliced cranberries after infusion, the “Instron” test measures the physical strength of the cranberries, and the “Scanning Electron Microscopy” test measures the morphology of the cranberry cells.

Brix Testing

In order to assess sugar concentration in cranberries, the Brix of the cranberries was measured. The Brix is the sugar percentage by mass of a solution (Bates, 1942). This parameter was used to determine the sugar mass percent of berries following the Infusion test, as well as to determine when a sample of berries was ready to undergo “Expression” testing. A refractometer was used to determine the Brix of each sample. In order to retain confidentiality on the exact values, a standard number according to Ocean Spray’s protocols was selected as 100% relative brix. Values stated are relative percentages to that.

Infusion

One criterion Ocean Spray uses to define a good cranberry is how well it infuses sugar syrup. This team used an Ocean Spray lab procedure in order to simulate the manufacturing process and investigate how freezing affects the infusion criterion.

Berries were infused in syrup for a standard amount of time as described in Ocean Spray’s methodology. Brix was taken before and after to quantify the amount of infusion.

Expression

Similarly to infusion, expression is a criterion that Ocean Spray uses to determine if a cranberry is a good cranberry. Expression is the term used by Ocean Spray to characterize a loss of syrup by a cranberry after infusion. In order to investigate the relationship between freezing protocol and expression, an Ocean Spray test was used. This test yielded quantifiable values for expression.

Instron Testing

The Instron test was developed in order to mirror a current Ocean Spray test run on never-frozen cranberries which determines their quality based on the force required to deform the berry 1mm. By attempting to develop a metric for the quality of a frozen-thawed cranberry based on its physical strength, the ultimate goal of this test was to create an in-house test that Ocean Spray could use to determine the quality of frozen-thawed cranberries in their production lines.

Thawed sample berries from each freezing protocol were tested for physical strength as a unit of force in newtons using an Instron machine. Additionally, berries that were not frozen were tested as a control. Five thawed berries were tested from the three different freezing protocols: Constant Temperature, Long Freeze, and Cyclic. Regular scotch tape was used to hold the cranberries upright. This ensured that the berry remained in the upright position throughout the test while not puncturing or deforming the berry. The Instron was set to a minimum and maximum threshold of -10 volts and +10 volts respectively. The Instron arm was extended to a maximum depth before the pressure arm retracted upward and data collection was concluded. The data were recorded in volts versus time.

Scanning Electron Microscopy

Scanning Electron Microscopy was used to determine how cranberry cells physically changed through various freezing protocols. After being frozen and removed from the freezer, several berries of each batch of frozen cranberries were cut with a razor blade. Each individual sample berry was cut to have flat and parallel surfaces as well as a uniform thickness. The cutting was performed while the berries were frozen. The cut berries were allowed to thaw before being spread over a plastic mesh and placed in a Magic Mill ® MFD-1010 Food Dehydrator. After 24 hours the berries were removed from the dehydrator. The berry slices were then sputtered in gold for 26 seconds and observed under an AMRAY 1830 scanning electron microscope (SEM) at 50x magnification, 100x magnification, and 300x magnification. The length scales of 50x and 100x magnification were chosen because on these scales cranberry cells could be seen in various levels of detail across a wide field at the sample locations. The 300x magnification length scale was chosen in order to provide a very detailed image of a very small number of cells. The areas imaged were the skin-cell interface as well as the cell structure between the skin and the seed vacuole. The skin-cell interface was chosen as it is the site where the berries are first exposed to freezing conditions. The flesh of the berry was also imaged as it is the largest uniform cell structure in a cranberry. Two to three berry slices were imaged per freezing protocol. The SEM images were then analyzed in ImageJ for roundness. A method to quantify the roundness of cells was needed in order to quantify the change in cellular morphology of cranberries as they underwent freezing. In order to compare the roundness, this quantity would also have to

normalize for the size difference of different samples. Taking this into account, aspect ratio was chosen to compare the roundness of cranberry cells across different samples. The aspect ratio is the dimensionless number that results from dividing the length of the cranberry cell by its width. By assuming that the cranberry cells are ovular or nearly spherical, the aspect ratio describes directly how round the cells are. The aspect ratio also factors out the size of the cranberry cell allowing for easy comparison between different samples of cranberry.

Following the conclusion of other tests, the microscopy data was compared to the results of those tests in order to determine what changes in the cranberry cells could lead to the observed changes in the other physical properties of cranberries.

Results and Discussion

Infusion

Samples from each freezing profile underwent the infusion and Brix testing processes. Figure 5 displays the results obtained by the infusion test.

Table 1: Infusion Results

Freezing Protocol	Days subjected to Protocol	Relative Brix after Infusion
Constant Temperature	33	0.83
	40	0.91
	45	0.90
	47	0.90
	49	0.97
	56	0.95
Cyclic	7	0.95
	21	0.97
Long Freeze	75	0.93
	110	1.00

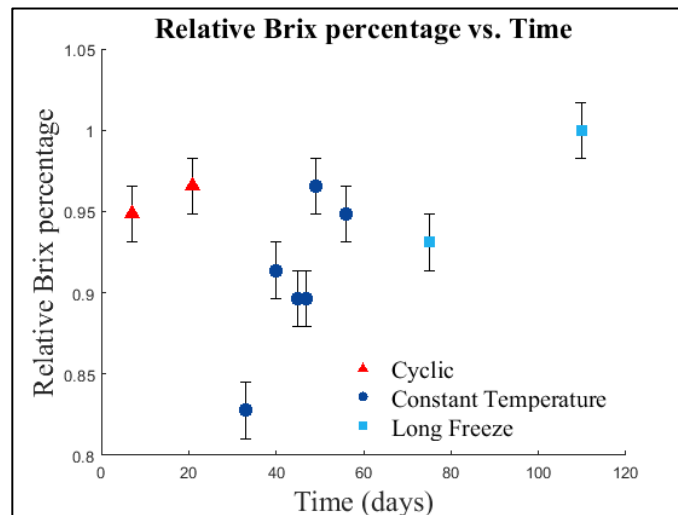


Figure 5: Brix percentage versus Time

As seen in Table 1 and Figure 5, sugar content increased with increased time subjected to freezing among all freezing protocols: Cyclic samples increased by 1.7% relative sugar by mass over 14 days, Constant Temperature samples increased by 12% relative sugar by mass in 23 days, and Long Freeze samples increased 4% sugar by mass over 35 days. While all freezing protocols achieved 97% Brix by the conclusion of their sampling periods, Ocean Spray manufacturing calls for a final relative Brix of 100%. Of all three freezing protocols, only Long Freeze achieved 100% relative Brix, and only after 110 days. The Constant Temperature

protocol may have achieved 100% if the sampling period had been extended, however. The Cyclic protocol may also have reached 100% relative Brix if the sample period were extended, but by the end of the sampling period the berries undergoing the Cyclic procedure were spoiled and growing visible fungus. Therefore, even had they achieved 100% relative Brix, this method would be inadvisable for use by Ocean Spray. Performing a linear regression on each data set from Table 1 yields Table 2.

Table 2: Slopes and Intercepts of Brix by Freezing Protocol

Freezing Protocol	Change in Relative Brix	
	per Day Frozen	Intercept
Constant Temperature	0.005 ± 0.001	.67 ± 0.07
Cyclic	0.0017	0.95
Long Freeze	0.0017	0.76

Table 2 summarizes the slopes and intercepts of the linear regression lines drawn through the infusion data presented in Table 1. The greater change in brix per day frozen for the Constant Temperature protocol compared to the Cyclic and Long Freeze protocols may indicate that berry infusibility increases at a faster rate with this freezing protocol. The intercepts represent the theoretical Brix that would have been measured if the berries were frozen until initial nucleation were complete and then thawed and infused. The intercepts of the lines may also reveal some information about initial freezing of the berries; the greater the intercept, the more disruption may have occurred during the initial freezing. Due to the low number of samples in all rounds of testing it is impossible to draw definite comparisons between the different freezing protocols. More investigation is needed to develop these results further.

Expression

Samples from all freezing profiles underwent expression testing. Following the infusion test, the samples were brought to the brix level Ocean Spray’s protocols require. These berries did not express at all; instead the pads frayed and clung to the berries as seen below.



Figure 14. Post-expression berries and pad. No expression onto pads; pads sticking to berries.

These results were not expected. Ocean Spray frequently observes expression from SDCs and the lack of expression in these tests is concerning. It is possible that there is a difference in the methodologies that Ocean Spray and this team used, and that this difference caused the lack of expression. Future teams should directly observe Ocean Spray's methodology in order to control for this possibility.

Instron Testing

Samples from each freezing profile were tested using an Instron machine. Each test resulted in similar data among all the samples in the voltage output. Tests were conducted on bread, balls of tape, and wood chips to determine if the materials of varying strengths yielded similar results. The tests displayed a voltage within a 1.5 volt error that the cranberry tests showed. This led the team to believe that the device was not functioning properly. The graphs in the Appendix B illustrate the control test outputs, which were conducted on non-frozen berries. The secondary graph is the average of all results from the "Constant Temperature" days 40 to 56, Long Freeze, and Cyclic tests, since the output information for these weeks were within 1.5 volts. Attempts to calibrate the machine failed. The machine did not provide a force reading when subjected to the force of the calibration weights. When the weights were hung from the Instron arm, a neutral output reading was given instead of an expected voltage. Due to these technical difficulties, this group believes the Instron machine that was used to be faulty, and the data invalid.

Scanning Electron Microscopy

Based on the methods for SEM, all samples except Constant Temperature 40, 45, and 49 underwent SEM imaging. Representative images of each sample have been collected below.

Visual Comparison of Representational Scans

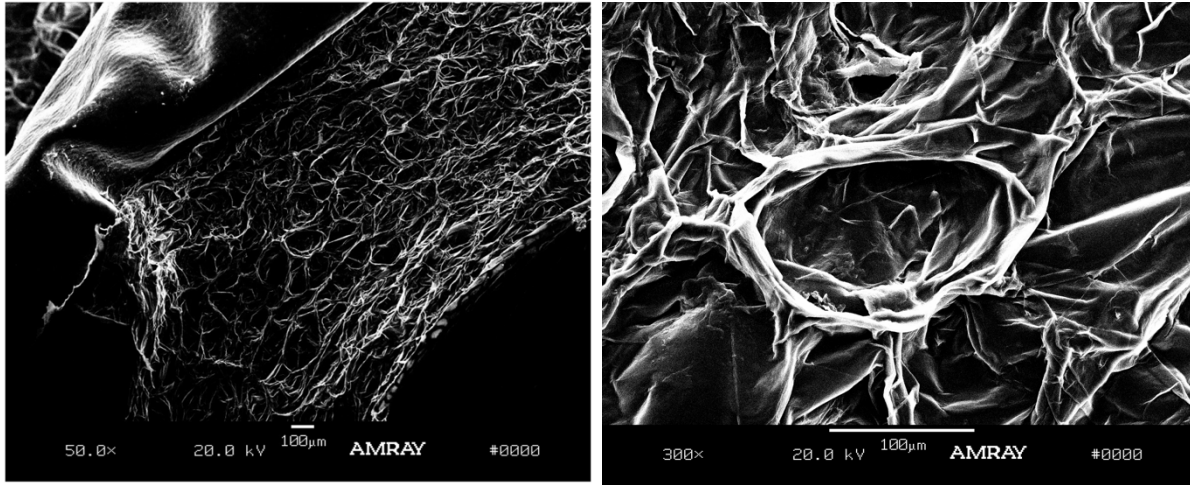


Figure 6: Representative scans of a never-frozen cranberry at 50x and 300x magnifications. These scans show the flesh of the berry.

Figure 6 shows representative SEM scans of a cranberry that had never been frozen. At a magnification of 50x, individual cells on the cross-sectional surface of the berry flesh can be seen. At 300x magnification, specific features of cells can be seen. The cell walls appear robust and well defined, with cells that have an oblong or elliptical shape. This is expected as without freezing, the cranberry cells were not subjected to the osmotic forces during freezing that cause the loss of shape.

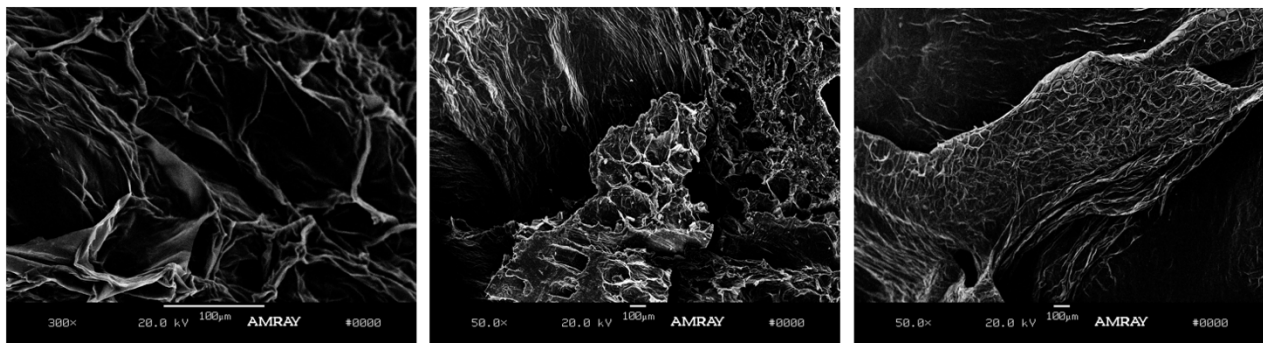


Figure 7: Representative scans of cranberries frozen with the Constant Temperature 33 (left), 47 (center), and 56 (right). These scans show the flesh of the berry at 50x magnification.

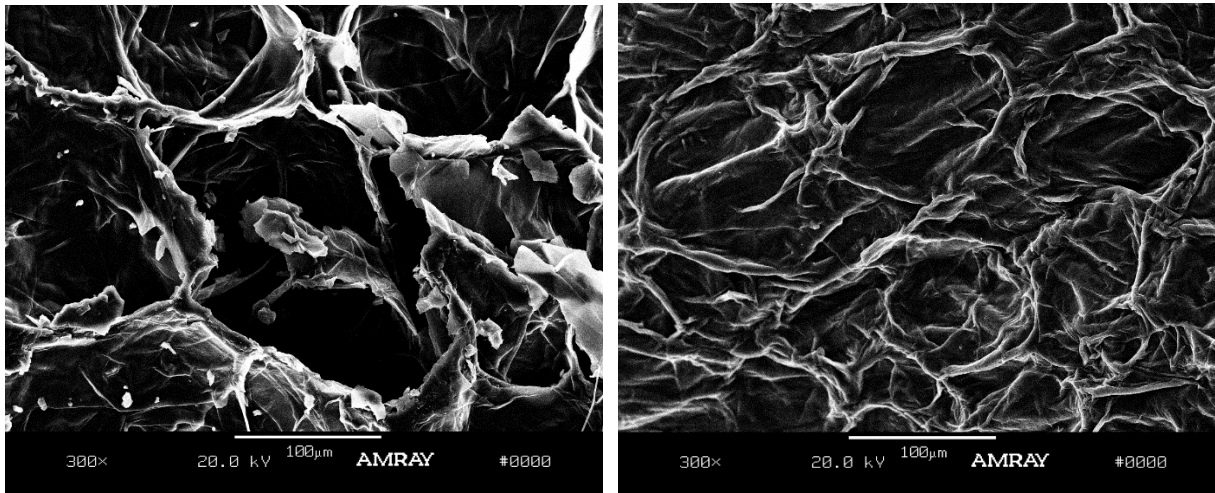


Figure 8: Close up of Constant Temperature 47 (left) and Constant Temperature 56 (right). At 300x magnification the difference in shape and cell wall integrity can be clearly seen.

Visually the scans of Constant Temperature 33, 47, and 56 are somewhat distinct as shown in Figure 7 but require a closer zoom to understand the differences more fully. Figure 8 shows a close-up of Constant Temperature 47 and Constant Temperature 56 where the different shape and cell wall integrity can be seen; the cells in Constant Temperature 47 appear more oblong and have frayed cell walls, while the cells in Constant Temperature 56 are rounder with mangled cell walls. Suitable 50x or 100x scans of Constant Temperature 33 were not taken. This limited the analysis of Constant Temperature 33 to 28 cells instead of the 50 called for by the methodology.

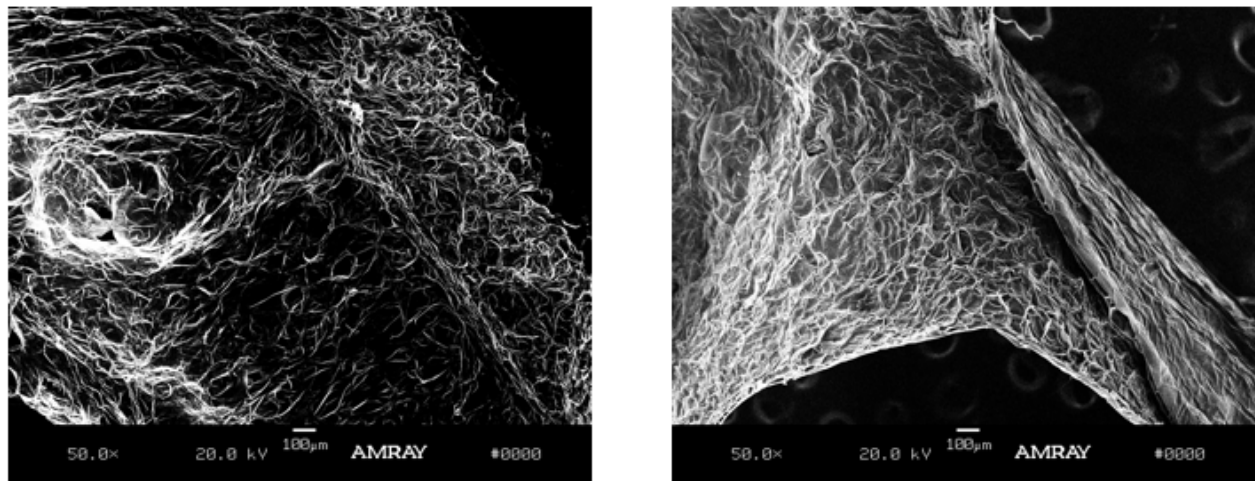


Figure 9: Representative images of cranberries frozen with Cyclic 7 (left) and 21 (right). These images show the flesh of the berry at 50x magnification.

Figure 9 shows that visually the cells in Cyclic 7 are quite long and stretched, while the cells in Cyclic 21 appear to be somewhat rounder. Similarly to the Constant Temperature scans, cells appear to be rounder after undergoing the Cyclic freezing protocol for a greater duration of time.

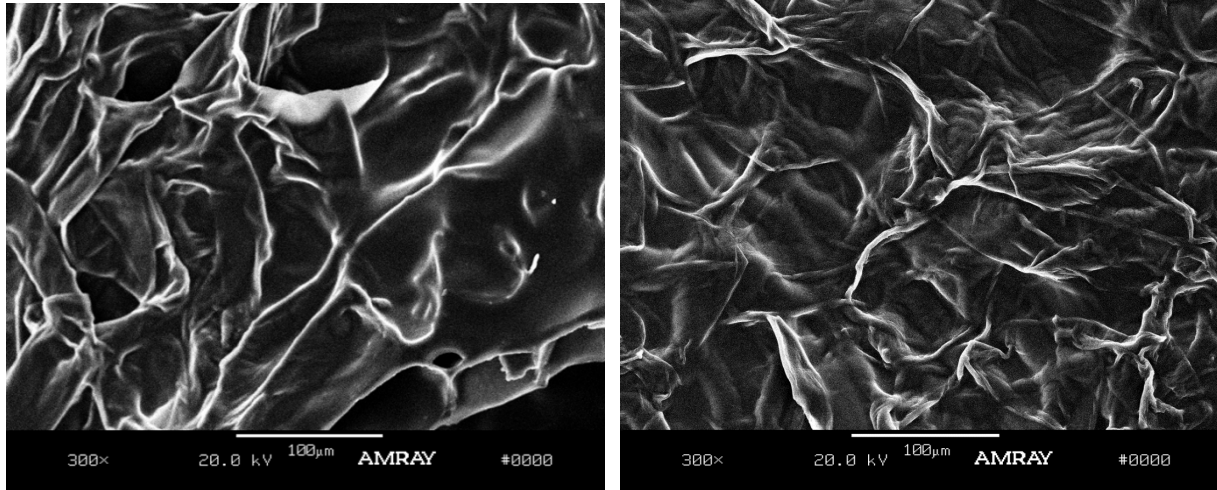


Figure 10: Close up of Cyclic 7 (left) and 21 (right). At 300x magnification cells are no longer distinct and cell walls are visibly nondescript.

Figure 10 shows that the cells of both samples are quite disrupted, with the cell walls are very flat and torn, more so in Cyclic 21. This cellular disruption is consistent with literature studies that show cell membranes lose integrity with freezing (Wojtas, 2009). The change in the roundness of the cells is also visible; Cyclic 7 has very long cells, whereas Cyclic 21 may have rounder shapes.

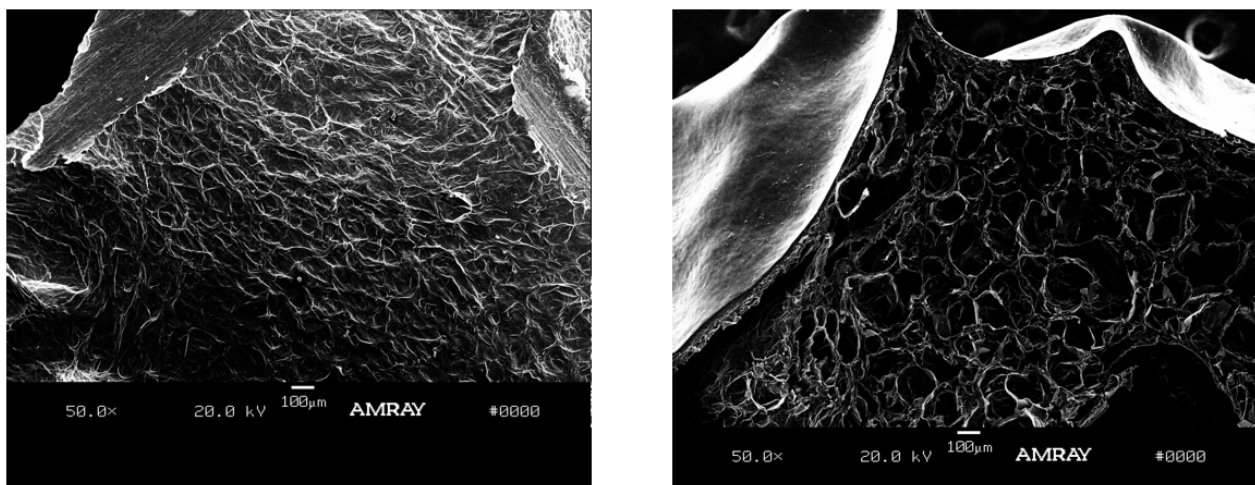


Figure 11: Representative images of cranberries frozen with the Long Freeze 75 (left) and 110 (right). These images show the flesh of the berry at 50x magnification.

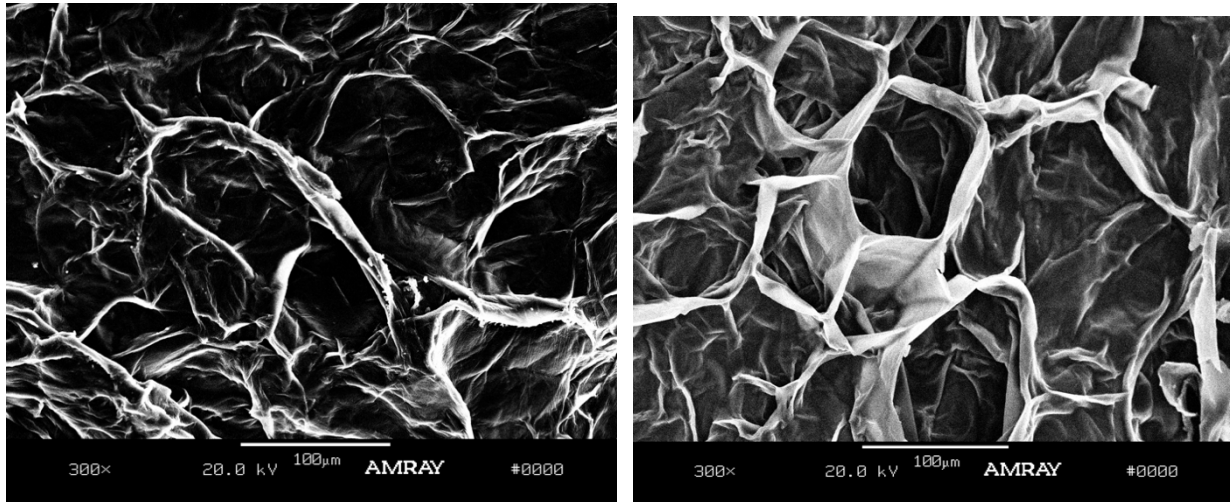


Figure 12: Close up of Long Freeze 75 (left) and 110 (right). At 300x magnification the cell walls and shape are distinct.

Figure 11 shows that the cells in the Long Freeze 110 sample have physically separated. This could be due to the formation of ice in intercellular space, displacing the cells and opening up gaps between them (Wojtas et al., 1999). Figure 12 shows the Long Freeze 75 and 110 samples at 300x magnification. At this level of magnification, it is evident in Long Freeze 75 that the cell walls had lost significant integrity; the cell walls are visually thinner and appear to fray at the edges. This loss of integrity is once again consistent with the degrading effects of a slow freezing (Wojtas et al., 1999). The cells in Long Freeze 110 appear much rounder than those in Long Freeze 75.

With representative scans from each freezing protocol side by side, some trends are visible in all freezing protocols. Namely, the longer the berries were in the freezer the more visibly disrupted the cell walls became and each freezing protocol yielded rounder cells as freezing time increased. The change in the roundness of the cells is quantifiable and was selected as a potential physical property of cranberry cells that varies with freezing.

Comparison of Aspect Ratio

The cellular aspect ratios for each imaged sample were found and are analyzed below.

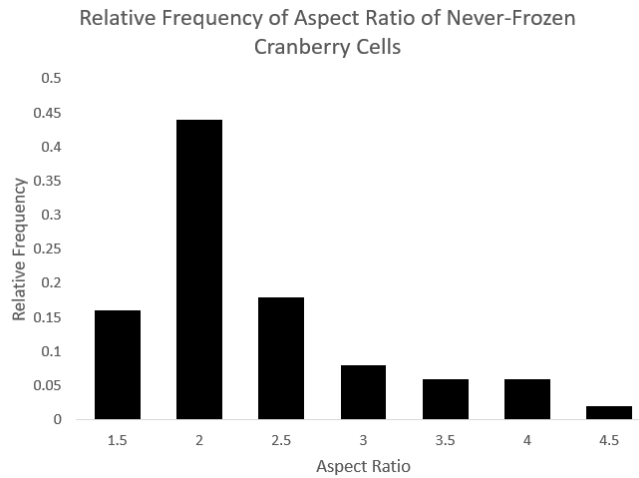


Figure 13: The relative frequency of the aspect ratio of never-frozen cranberries. This figure shows how likely a never-frozen cranberry cell is to have an aspect ratio of between 1.5 and 4.5.

Figure 13 displays the relative abundance of the aspect ratio of never-frozen cranberry cells. The aspect ratio of never-frozen berries can be seen to approximate a Poisson distribution with a median aspect ratio of 1.84 and a maximum of 4.28. The mode of the aspect ratio of never-frozen cranberry cells is between an aspect ratio of 1.51 and 2.00, and the distribution is skewed positively. Because these never-frozen berries did not undergo a freezing protocol, this sample was taken as a control sample.

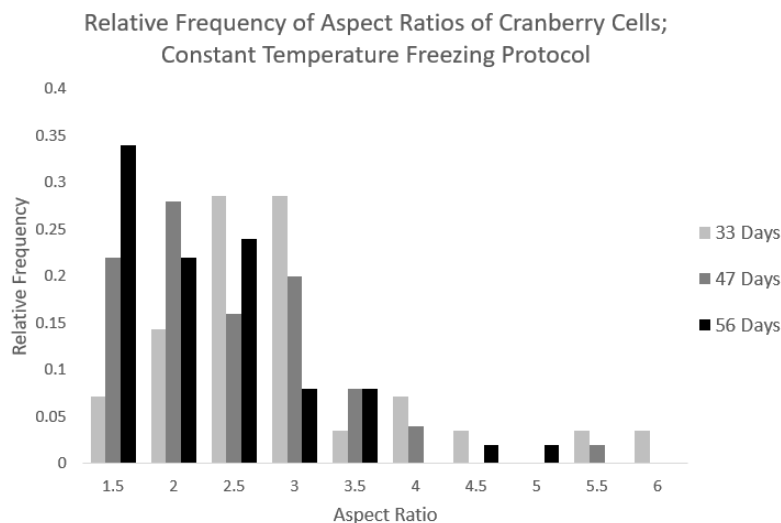


Figure 14: The relative frequency of the aspect ratio of Constant Temperature 33, 47, and 56. This figure shows how likely a cranberry cell that underwent the Constant Temperature protocol is to have an aspect ratio of between 1.5 and 6.

Figure 14 displays the side-by-side relative distribution of aspect ratios of all three imaged Constant Temperature samples. Altogether these data indicate that as freezing duration increases, the median and mode of the cellular aspect ratio decreases towards 1.0 with freezing duration. The decrease in the median value indicates that as the berries undergo freezing the berry cells become rounder and rounder. The maximum roundness also decreases with increasing freezing duration, which also indicates that berry cells become rounder with freezing duration.

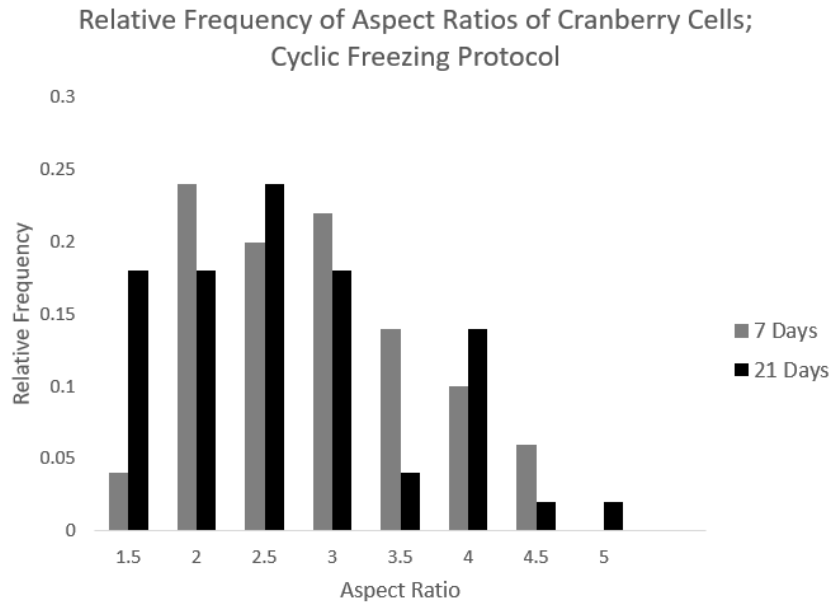


Figure 15: The relative frequency of the aspect ratio of Cyclic 7 and 21. This figure shows how likely a cranberry cell that underwent the Cyclic freezing protocol is to have an aspect ratio of between 1.5 and 6.

The aspect ratios of Cyclic 7 and 21 as shown in Figure 15 are slightly different. The aspect ratios of the cells from the Cyclic 7 sample form a positively skewed unimodal curve around 2.01 to 2.50. The cells in the Cyclic 21 sample form a nearly flat distribution with a median aspect ratio of 2.18. These data suggest that cyclic freezing may shift the cellular aspect ratio towards 1 with increasing freezing duration, but that this effect is rather small over the 14 day period separating the samples.

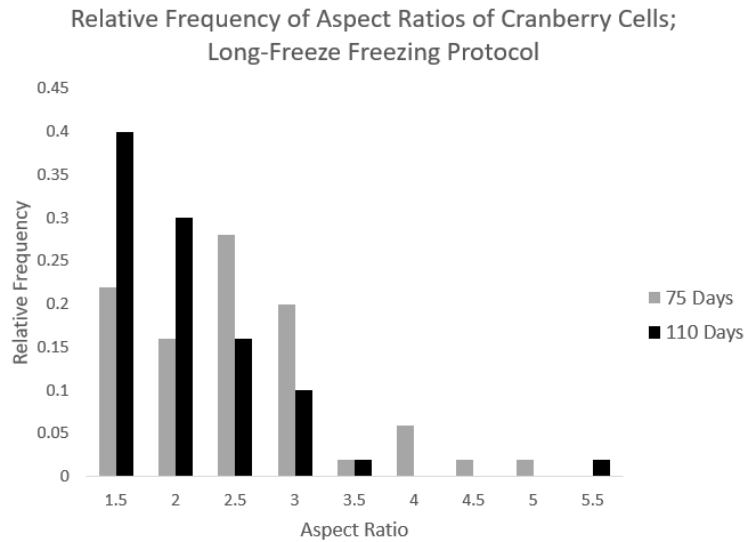


Figure 16: The relative frequency of the aspect ratio of the cells from the Long Freeze 75 and 110 samples. This figure shows how likely a cranberry cell that underwent the Long Freeze protocol is to have an aspect ratio of between 1.5 and 5.5.

The aspect ratios of Long Freeze 75 and 110 as shown in Figure 16 differ significantly. Where the mode of Long Freeze 75 was 2.01 - 2.50, the mode of Long Freeze 110 was between 1.01 and 1.50. This represents a large shift in the aspect ratio towards 1 over the 35 days that separate the samples.

Table 3: Summarized table of cellular aspect ratios

Freezing Protocol	Freezing Duration (days)	Aspect Ratio	
		Median	Maximum
Never-Frozen	-	1.84	4.28
	33	2.55	5.63
	47	2.05	5.35
Constant Temperature	56	1.83	4.88
	7	2.56	4.44
Cyclic	21	2.18	4.96
	75	2.26	4.53
Long Freeze	110	1.69	5.20

Table 3 is a summary of the aspect ratio data explored in Figures 13 through 16. As the duration of freezing increased, the aspect ratio of the cells in any given freezing protocol decreased. This trend was seen across all three freezing protocols tested. In the Constant Temperature protocol, the aspect ratio of cell samples decreased from 2.55 to 1.83 over the course of 23 days. In the Cyclic protocol, aspect ratio decreased from 2.56 to 2.18 over the course of 14 days. In the Long Freeze protocol, the aspect ratio decreased from 2.26 to 1.69 over the course of 35 days. While the effect of freezing duration on the aspect ratio of the cells was not a direct relationship, the data suggests some correlation. Also notable is that undergoing any freezing protocol appears to

increase the aspect ratio of the cells in all freezing protocols. All three tested freezing protocols had at least one sample with an aspect ratio greater than that of the control never-frozen sample.

The aspect ratio of any sample in any freezing protocol may have had to do with the cellular disruption that the berry sustained in that freezing protocol. It has been observed that allowing plant cells to freeze at temperatures above $-30\text{ }^{\circ}\text{C}$ causes water to freeze in the intercellular spaces, deforming and shrinking the cells (Petzold, 2009). The osmotic pressure of the crystalline ice then pierces the cell membrane and causes a loss in cell wall integrity (Allan-Wojtas et al., 1999). From this information, it is proposed that the cranberry cells may initially deform and lose cell membrane integrity when frozen due to intercellular freezing. Then, as the cranberry cells thaw and reuptake water, they may relax back to a rounder shape with the final shape being determined by the new strength of the cell membrane. As the freezing duration increases, the strength of the cell membrane slowly decreases, possibly leading to a rounder shape and lower aspect ratio.

It is important to note that over the duration of this test, only two to four SEM scans across two to four berries were recorded for each sample. This falls below the generally accepted statistical minimum from which to draw correlations. Therefore, conclusions and mechanisms proposed based on the SEM data should be taken as informed hypotheses to be investigated further.

Comparison of Aspect Ratio to Infusion Results

Ideally, the cellular deformation of cranberry cells can be related directly to the macroscopic physical properties of interest: infusion, expression, and strength. In order to relate the cellular aspect ratios and possible cell disruption to these properties, cellular aspect ratios were compared to infusion results.

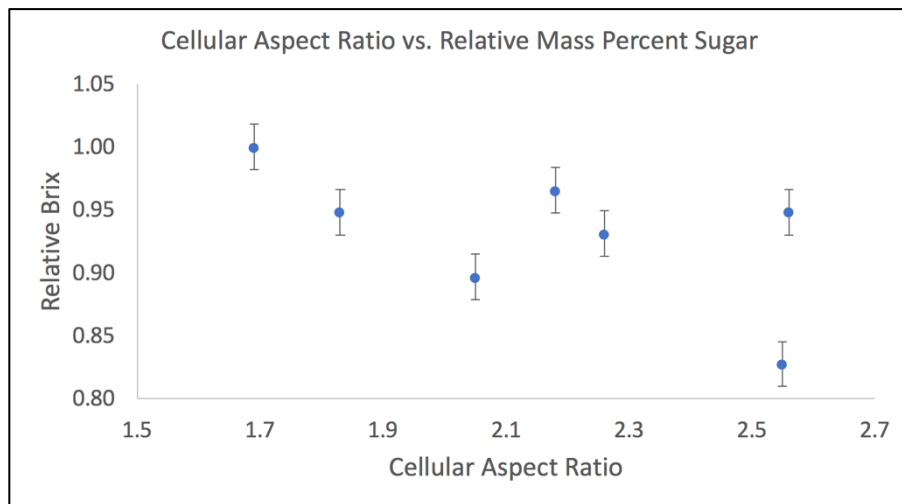


Figure 17: Comparison of mass percent sugar in cranberries after infusion to aspect ratio

Figure 17 shows the graphical comparison of infusion results to the cellular aspect ratio observed via SEM in a given sample. A linear regression of the data suggests a potential correlation between aspect ratio and infusion, but the correlation is extremely weak ($r^2 < 0.4$). This suggests that the mechanism governing infusion is not cellular aspect ratio, but some other property of cranberry cells. However, due to the small sample size of the SEM scans, the relationship cannot be discounted entirely and deserves a more rigorous investigation.

Comparison of Aspect Ratio to Instron and Expression

A comparison between cellular aspect ratio and berry strength or expression could not be performed due to a lack of valid Instron or expression data.

Conclusions

Infusion tests conducted on the different freezing profiles indicated that there may be a difference in infusibility between freezing protocols. Of all the freezing protocols, Constant Temperature had the greatest slope of Brix versus freezing duration, while Long Freeze attained the greatest Brix. Only berries that underwent the Long Freeze protocol attained the Brix that Ocean Spray uses in its production of SDCs. Due to the small sample size, more testing is needed to determine the relative magnitudes of the effects of freezing on cranberry infusibility. If this effect is reproducible it may have substantial throughput and yield implications for Ocean Spray.

With the methodology described, no expression was seen from any sample. However, it is possible that the methods used were not adequate to induce expression in a measurable way. This may be due to differences between Ocean Spray's methodology and that used in this project.

The Instron data was inconclusive due to faulty instrumentation. The recorded data of volts relative to time were not enough to determine the effects that the different freezing profiles had on the strength of the berries.

Freezing protocol and duration may have impacted the shape and structure of cranberry cells. Across the three tested freezing protocols, the cellular aspect ratio increased with initial freezing and decreased as the freezing duration increased. Freezing protocol and duration may also have had an impact on the integrity of the cell walls of the cranberry cells with initial freezing and longer freezing duration both leading to less integrity. A possible mechanism relating aspect ratio and cell wall integrity was proposed; the cranberry cells may initially deform and lose cell membrane integrity when frozen due to intercellular freezing. Then, as the cranberry cells thaw and reuptake water, they may relax back to a rounder shape with the final shape being determined by the new strength of the cell membrane. As the freezing duration increases, the strength of the cell membrane slowly decreases, possibly leading to a rounder shape and lower aspect ratio.

Recommendations

Excel has a maximum amount of data that it can handle before it stops LabView from collecting. This team has found that the lab computer can handle about 30MB before it stops collecting. This translates to around 311,000 rows by 9 columns. To ensure that data collection does not stop, it is recommended that a new file be created every 10 days. Additionally, it is possible for the LabView program to malfunction, so it is recommended to check on the LabView program itself.

This team suggests that future project teams consider methods for Cyclic freezing protocols. By the end of the sample period, the berries had spoiled from being frozen and thawed repeatedly. This may be mitigated by varying the temperature between 28 °F and 35 °F. It has also been noted that this could be a very energy intense freezing protocol. Further investigation into this may also be needed.

This team suggests future groups also test a fast freeze method: hold the freezer temperature at -40 °C while freezing the berries. Literature indicates this may disrupt the cells of the cranberries less, as water will freeze inside the cells rather than freeze in the intercellular space (Petzold, 2009). This may lead to a decrease in infusion and expression.

The large problem with the infusion test was the lack of samples drawn. With only two samples for the Cyclic and Long Freeze protocols, and only six for the Constant Temperature protocol, it is impossible to draw strong conclusions. This team suggests that future project teams take more infusion samples. Because infusion is a rather time-consuming process, this team suggests that the next project team allocates more manpower to infusion, as well as run multiple infusion samples in parallel. This will allow for a more rigorous examination of the relationship between freezing protocol and infusion. In addition, larger amounts of berries used for Brix testing yield less potential for error; it is suggested that future teams use at least 30 g of berries when testing for Brix.

Expression testing evolved over time; however, no expression was ever seen. It is recommended that future teams start with the protocol described in the methodology. Ocean Spray recommended keeping the berries in a hot room, between 90-100 °F, during the two weeks that the berries are allowed to sit. It is believed that this will help see expression. Primarily, it is recommended that future teams travel down to Ocean Spray laboratories and observe the expression test being conducted. In doing so, it can be confirmed that the methodology described matches with Ocean Spray's. A control test was conducted on berries before dehydration. These berries at 53% Brix, expressed immediately, with no dehydration. The berries expressed to such an amount that the pads were completely saturated, the cup contained liquid, and the weight also had syrup on it. Given that no expression was seen at 78-82% Brix, future teams might consider picking a value in between 53% and 78% Brix. By doing this, there is a greater chance of expression, in a measurable quantity. This would be differing from the standard protocol of Ocean Spray, so the exact level of Brix would need to be held constant and recorded.

The data taken from the Instron testing is invalid. It is recommended that a different machine be used by future teams. This team also recommends that future teams find a calibration curve for

the Instron machine that is used before testing the berries. This will allow for an easier time representing the data.

In order to obtain a more detailed and rigorous understanding of cranberry cell properties as they vary with freezing duration and protocol, a more in-depth study of the cell shape and structure is recommended as follow up to this report. It is recommended that future studies take more frequent and more comprehensive SEM scans of cranberries during the freezing process. Specifically, at least one image from four different cranberries undergoing the same freezing protocol should be scanned at the same time. This will allow for statistically significant findings and strengthen any results that are obtained via SEM analysis.

References

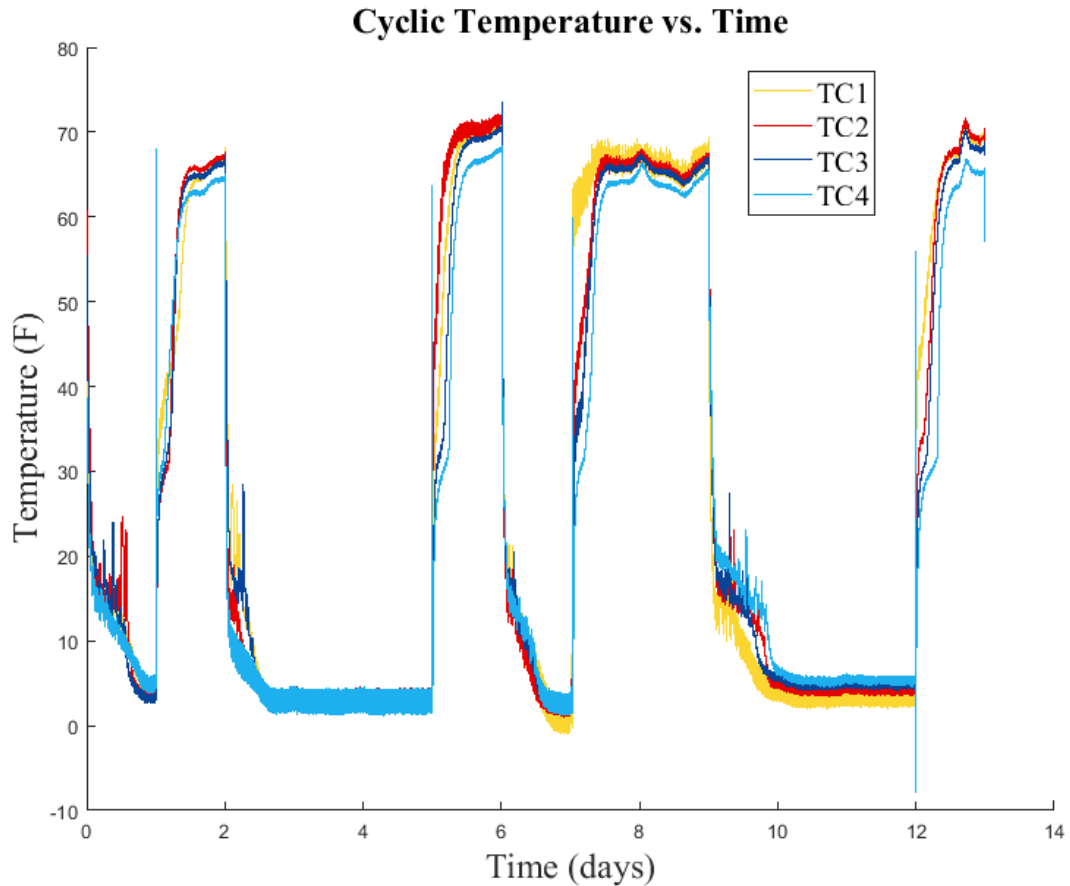
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- Petzold, G. & Aguilera, J.M. *Food Biophysics* (2009) 4: 378. <https://doi.org/10.1007/s11483-009-9136-5>

Appendices

Appendix A: Cyclic Temperature versus Time – Full Length	32
Appendix B: Instron Voltage Data versus Time.....	33
Appendix C: SEM Micrographs	35
Appendix D: The Impact of Free Trade Agreements on The Ocean Spray Cooperative	46

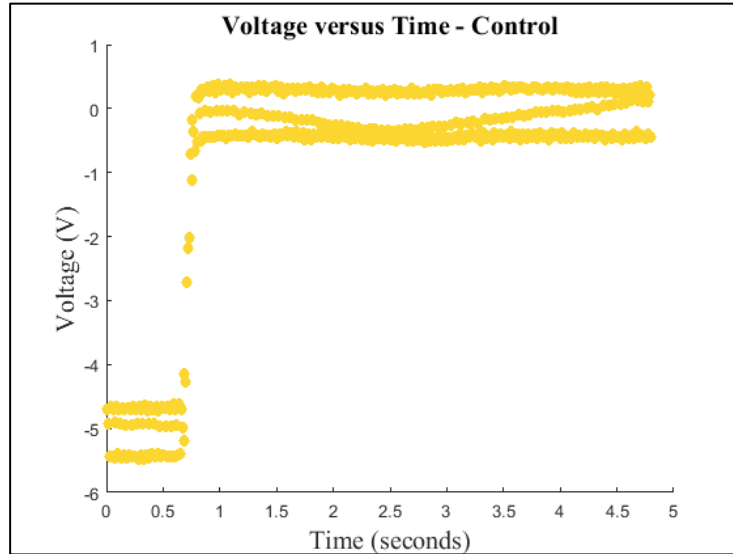
Appendix A: Cyclic Temperature versus Time – Full Length

In carrying out this project, data collection encountered a number of issues. A portion of the below graph, day five through day seven, was included in the main body of the text for clarity. Below is a graph of all collected data regarding the Cyclic protocol. Data collection was terminated after thirteen days due to an Excel file size limitation.

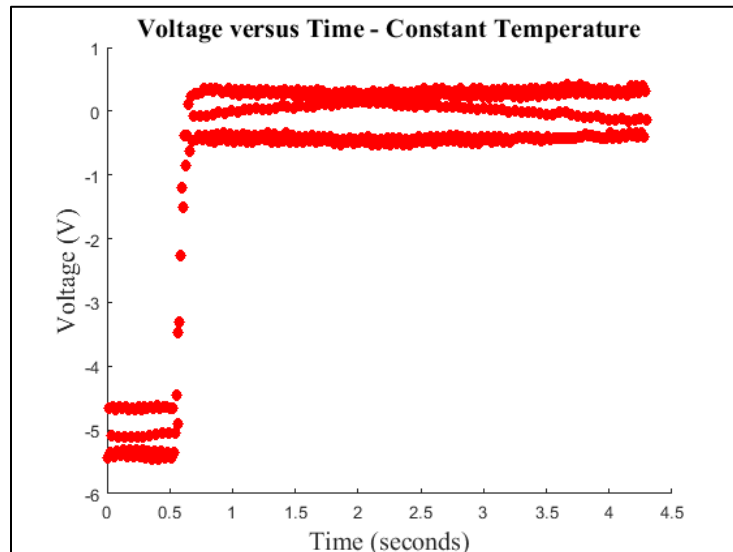


Appendix B: Instron Voltage Data versus Time

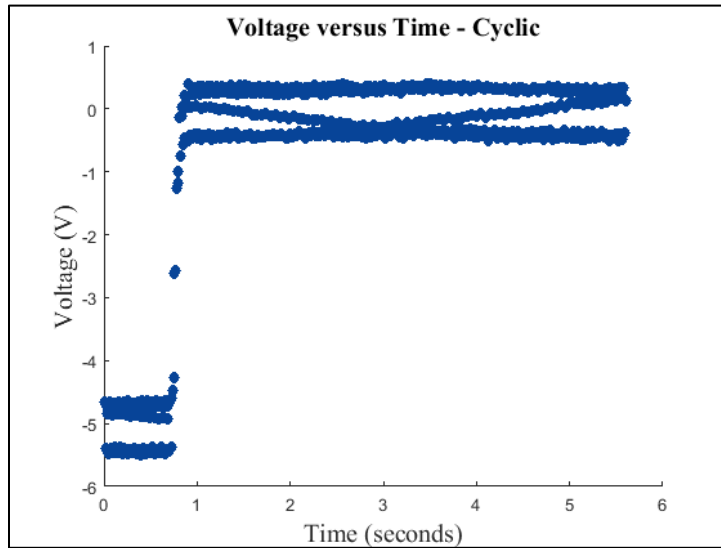
Below is the time versus voltage data collected as part of the force testing as described in the methodology. The appearance of three data sets per graph is due to the three sensors present on the Instron arm. This project team believes the data to be invalid, but it is reported for completeness.



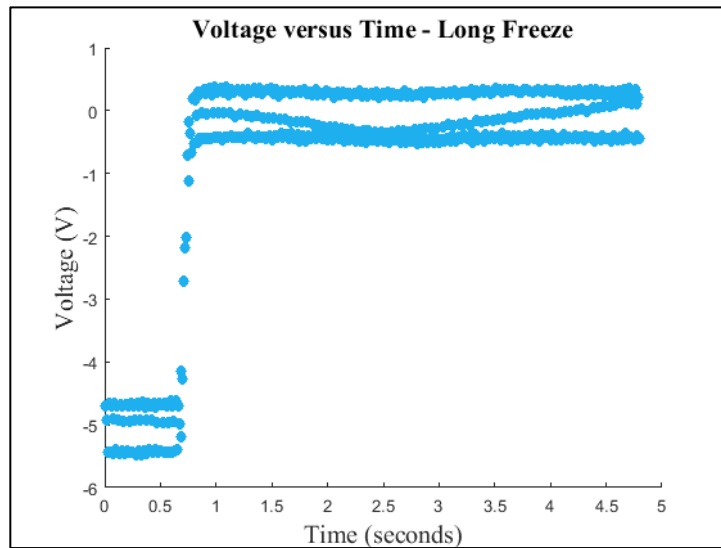
Voltage versus Time: Never-frozen berries



Voltage versus Time: Constant Temperature Protocol



Voltage versus Time: Cyclic Protocol

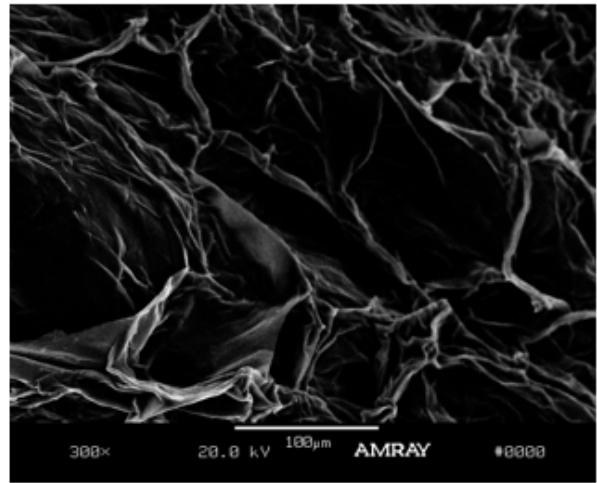
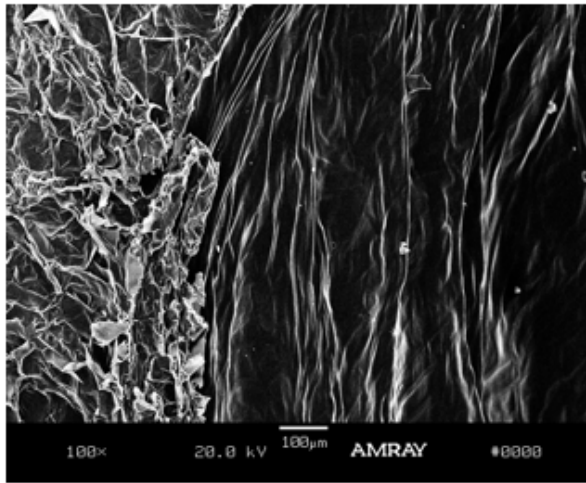


Voltage versus Time: Long Freeze Protocol

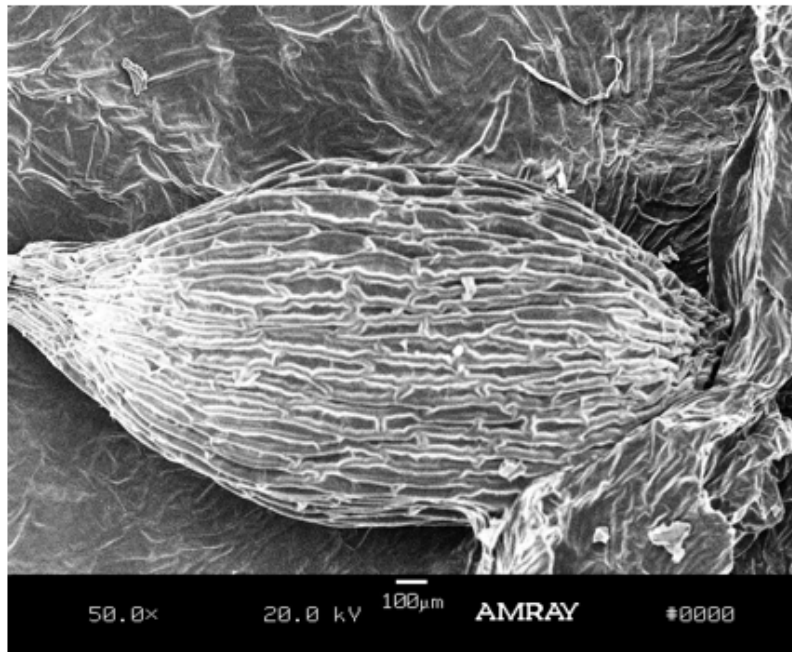
Appendix C: SEM Micrographs

In this section are every micrograph taken via SEM. The appendix is further broken up into sub-appendices regarding Constant Temperature, Cyclic, and Long Freeze protocols individually. Higher resolution images may be available by contacting the project team.

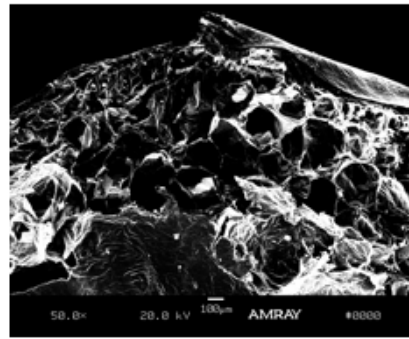
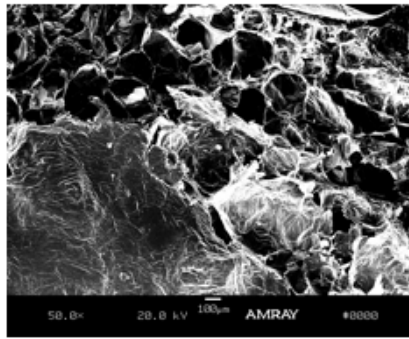
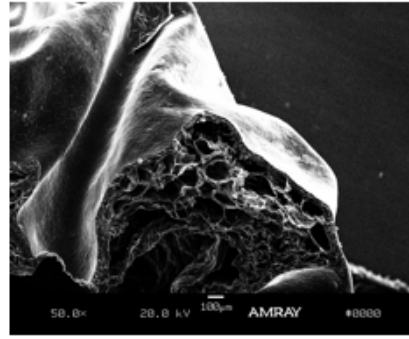
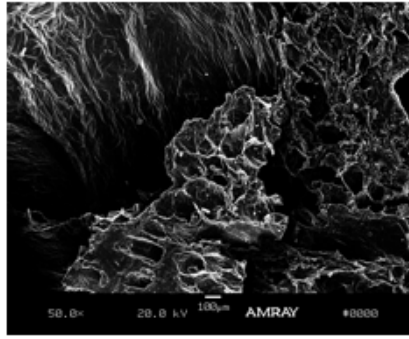
Appendix C-1: Constant Temperature Micrographs



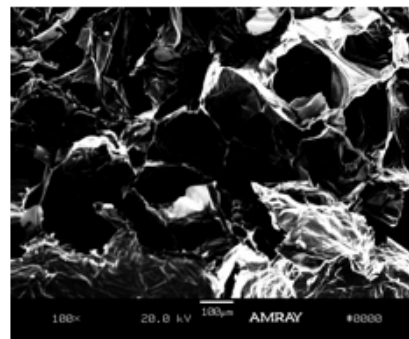
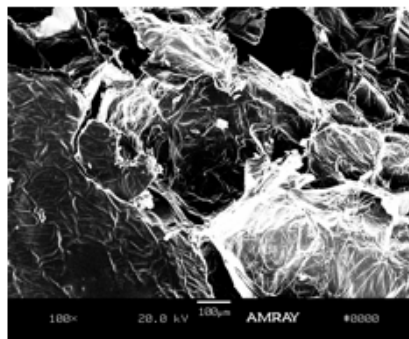
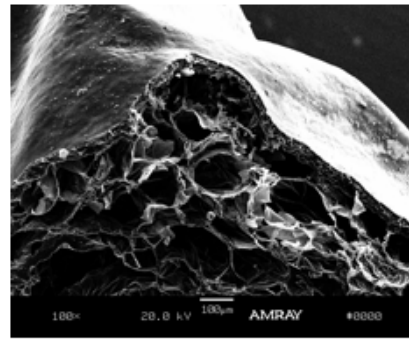
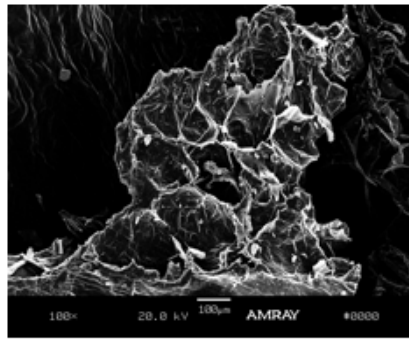
Left: Constant Temperature 33: 100x magnification; Right: Constant Temperature 33: 300x magnification



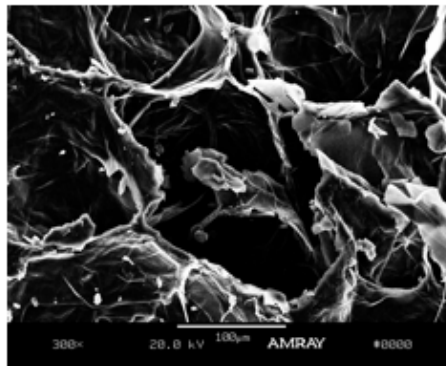
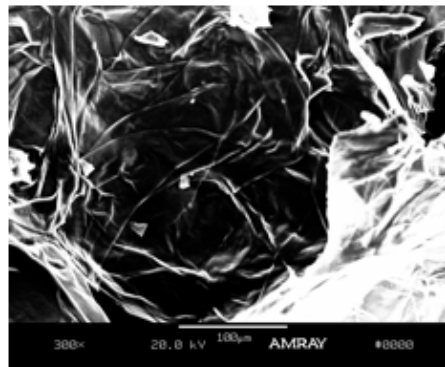
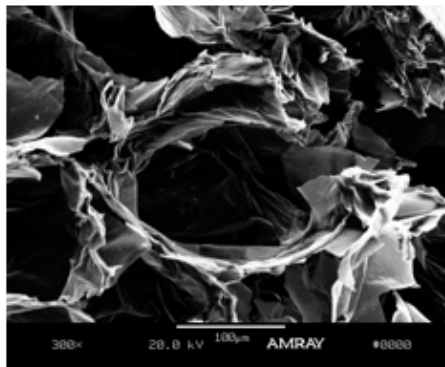
Constant Temperature 40: 40x magnification



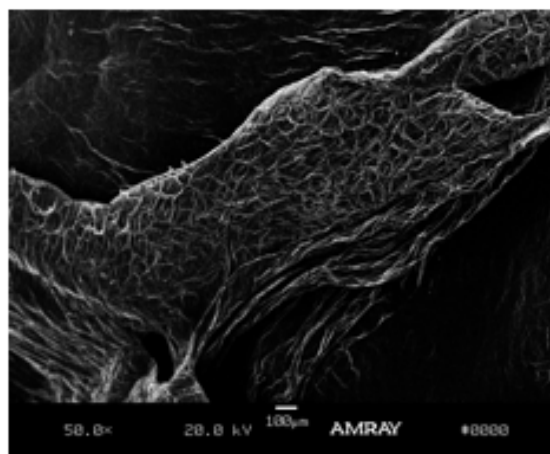
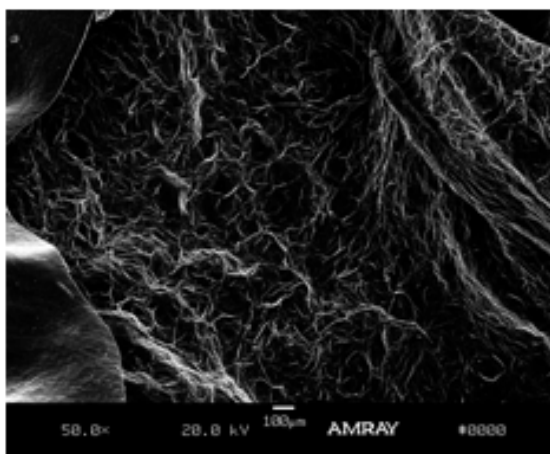
Constant Temperature 47: 50x magnification scans I-IV



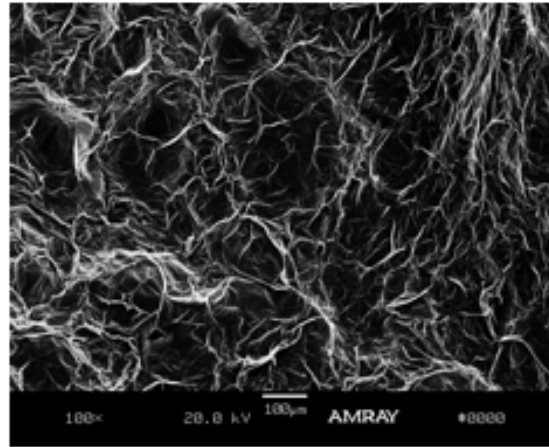
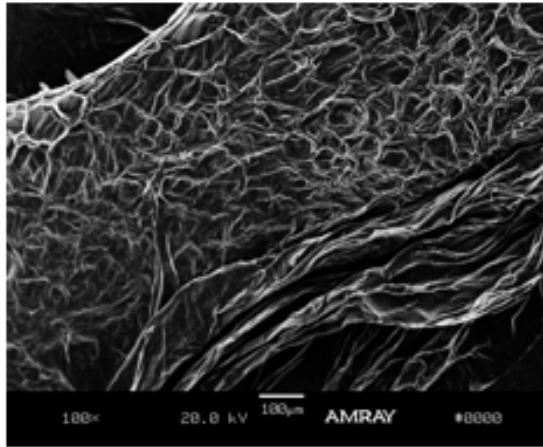
Constant Temperature 47: 100x magnification scans I-IV



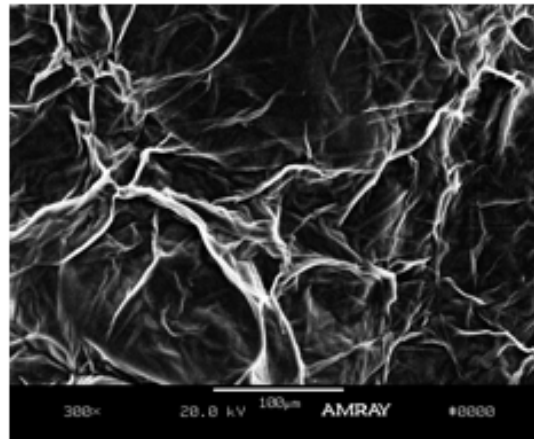
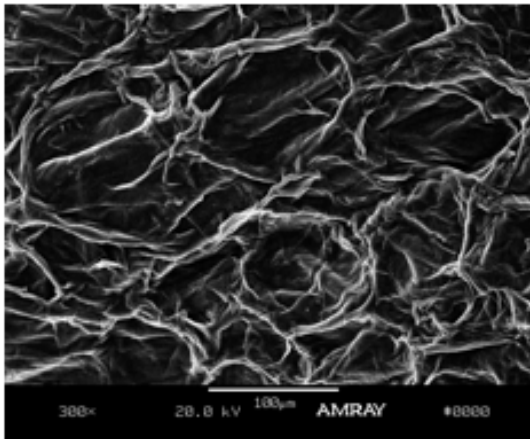
Constant Temperature 47: 300x magnification scans I-III



Constant Temperature 56: 50x magnification scans I-II

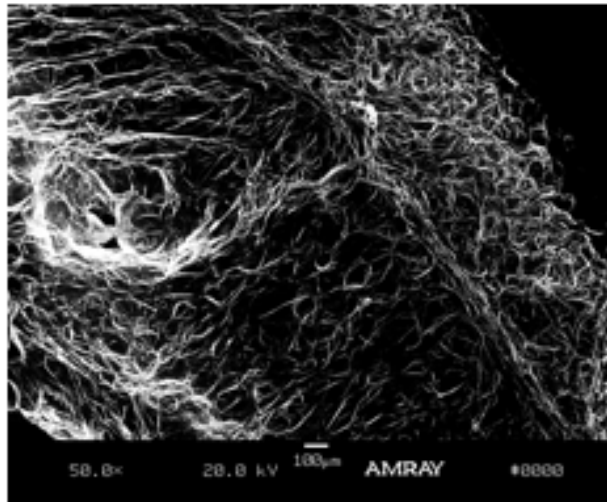


Constant Temperature 56: 100x magnification scans I-II

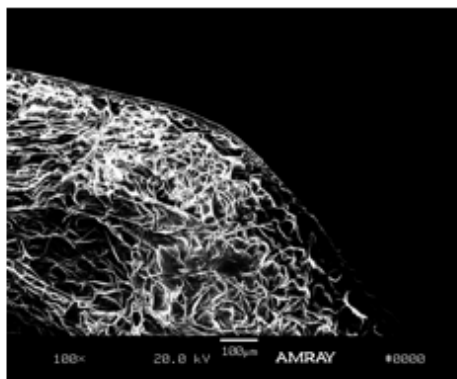
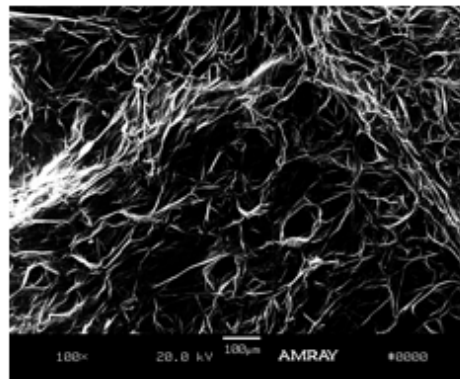
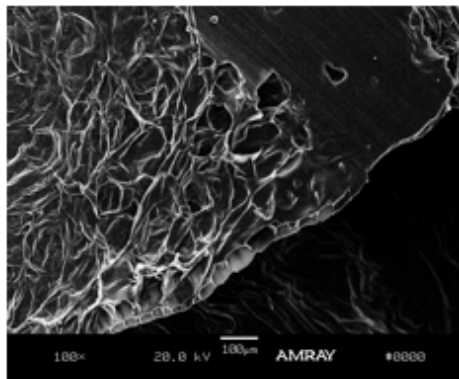


Constant Temperature 56: 300x magnification scans I-II

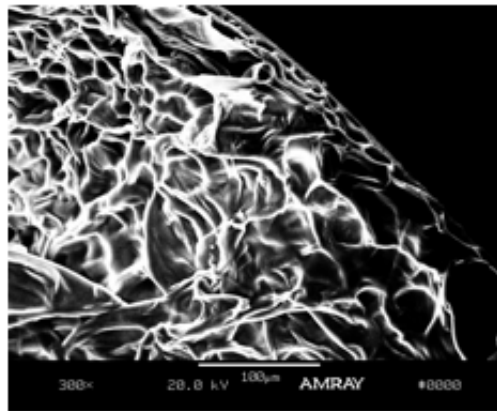
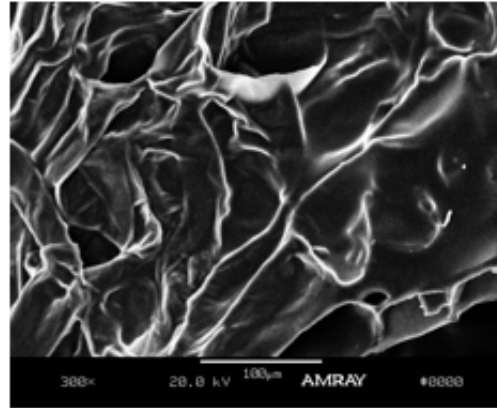
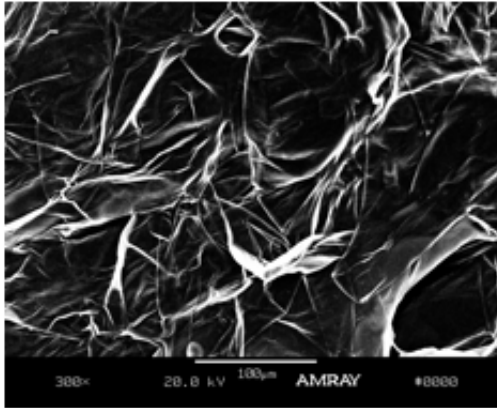
Appendix C-2: Cyclic Micrographs



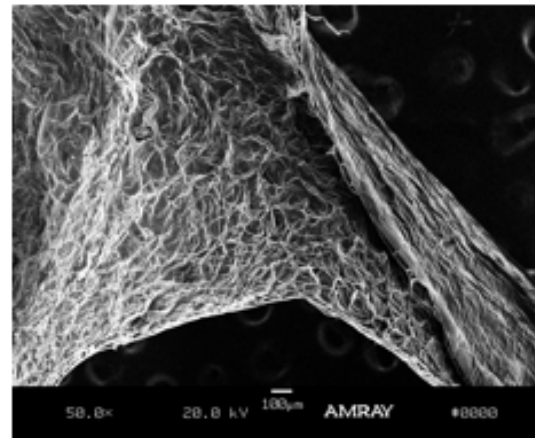
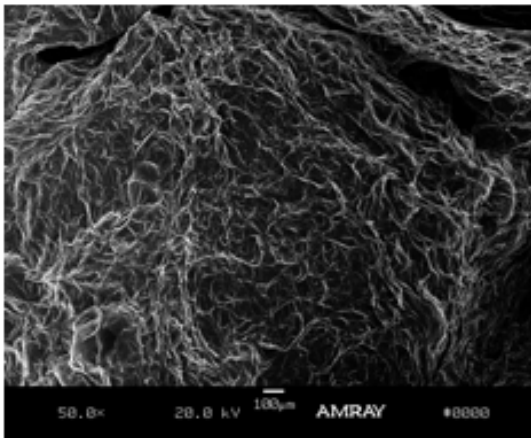
Cyclic 7: 50x magnification



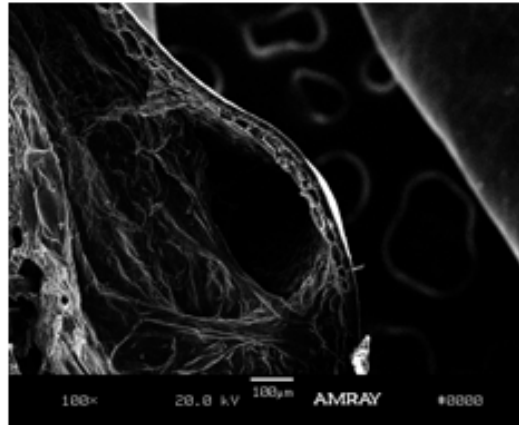
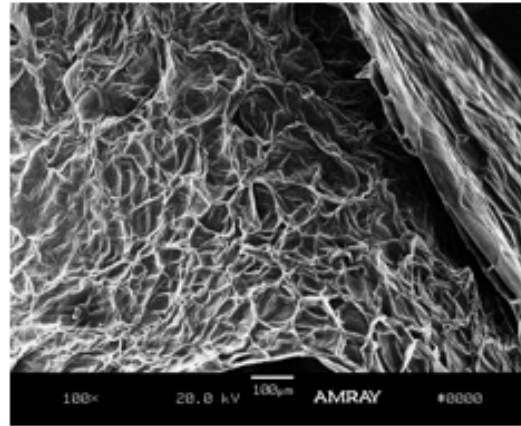
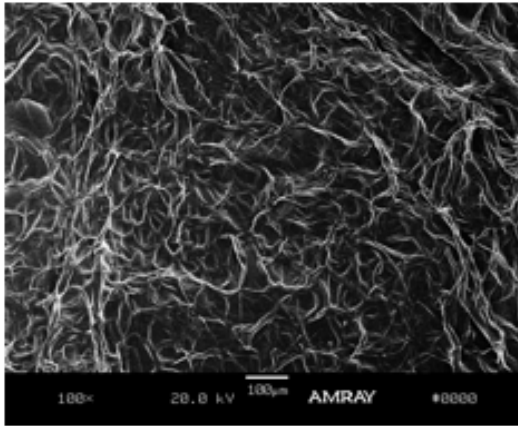
Cyclic 7: 100x magnification scans I-III



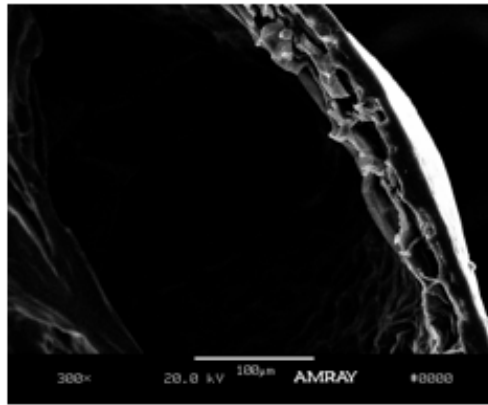
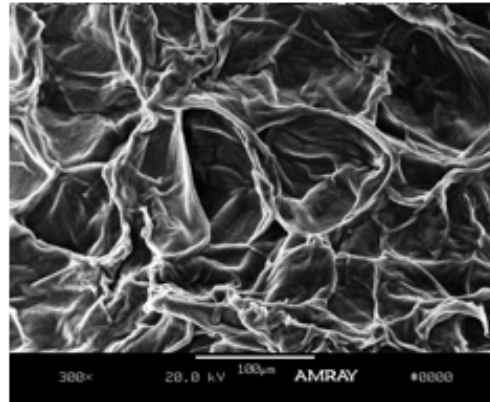
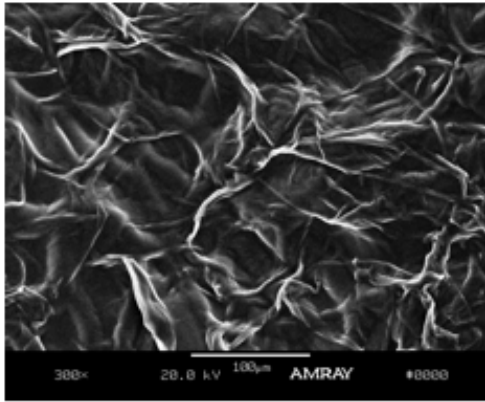
Cyclic 7: 300x magnification scans I-III



Cyclic 21: 50x magnification I-II

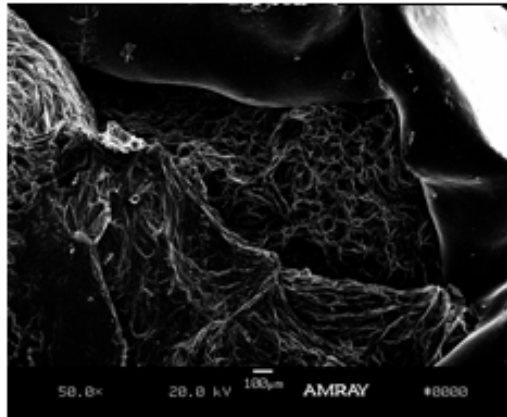
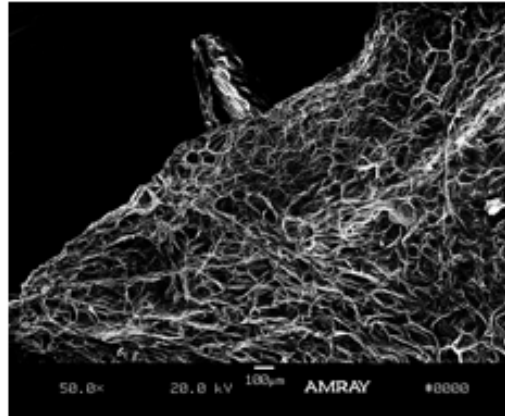
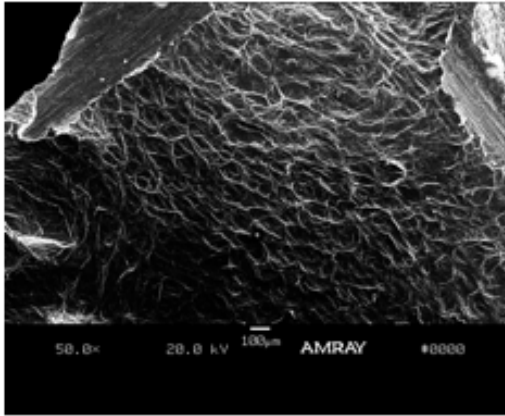


Cyclic 21: 100x magnification I-III

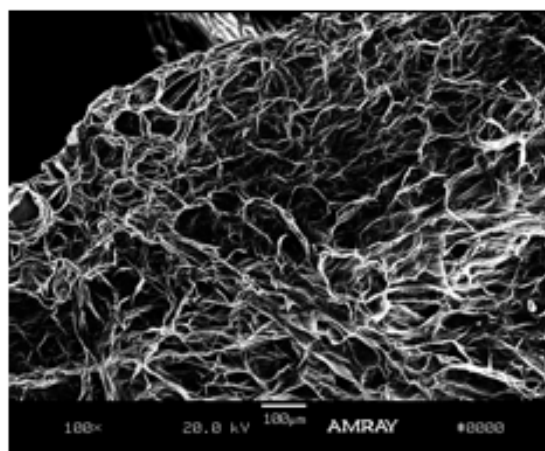
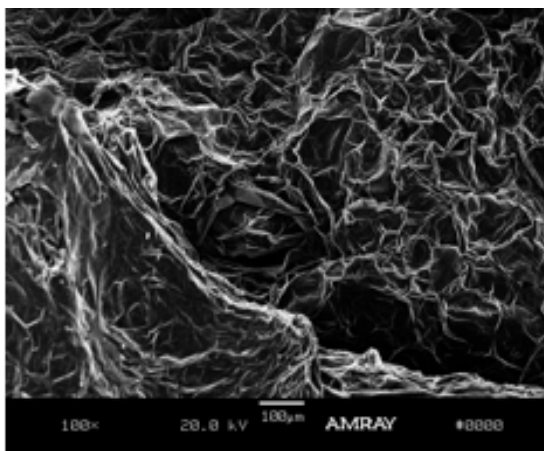


Cyclic 21: 300x magnification I-III

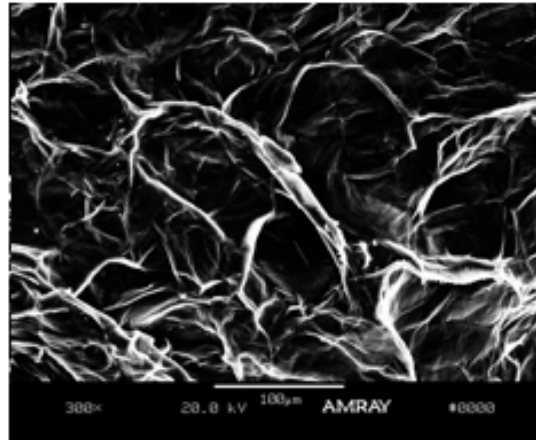
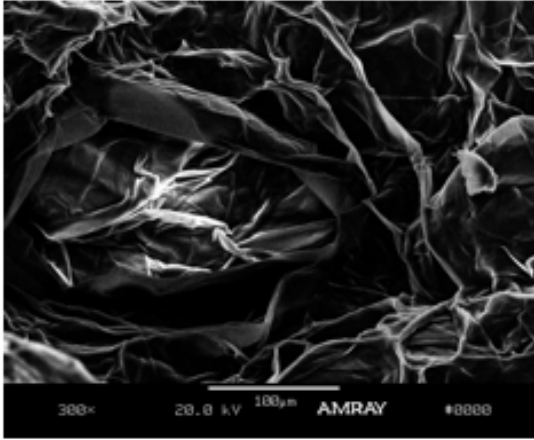
Appendix C-3: Long Freeze Micrographs



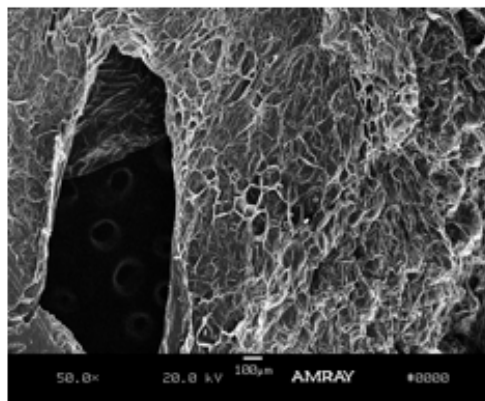
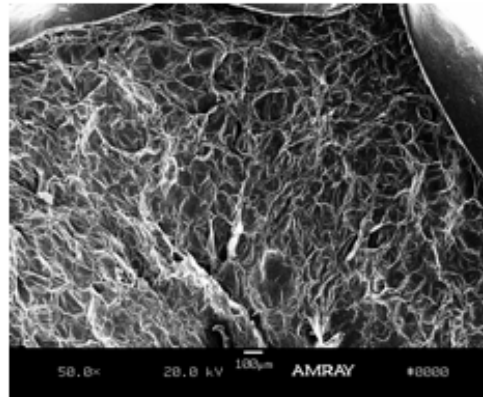
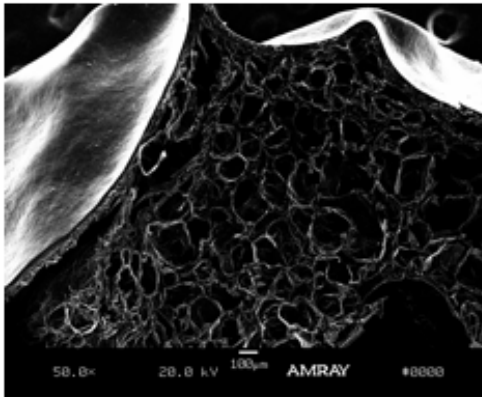
Long Freeze 75: 50x magnification scans I-III



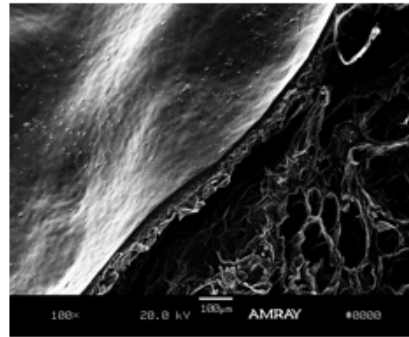
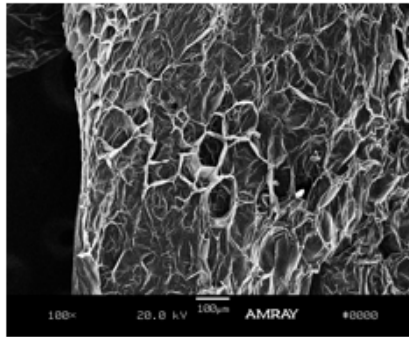
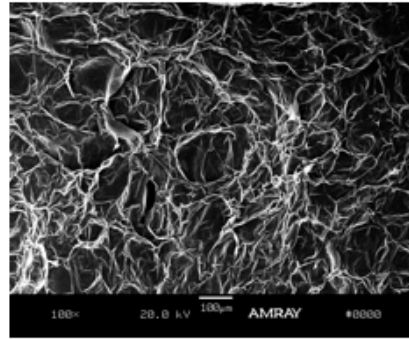
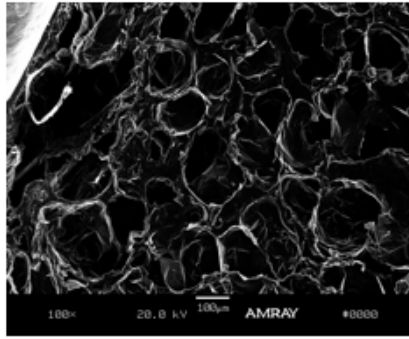
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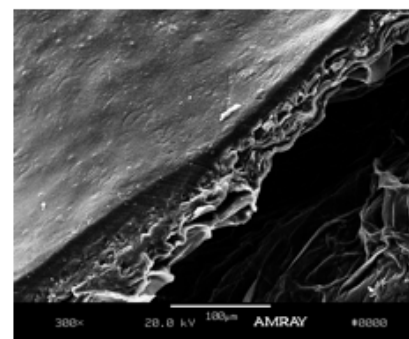
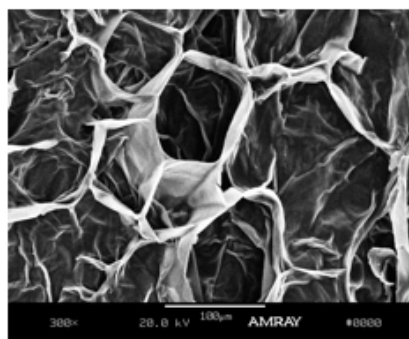
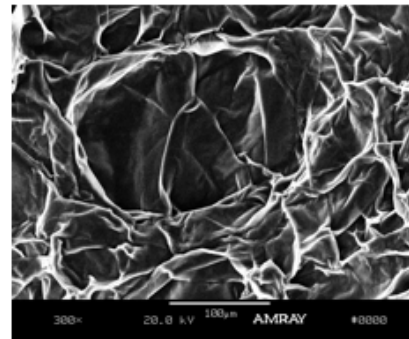
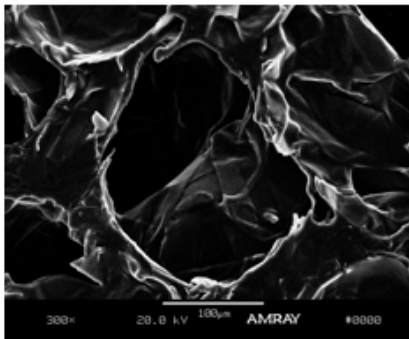
Long Freeze 75: 300x magnification scans I-II



Long Freeze 110: 50x magnification scans I-III



Long Freeze 110: 100x magnification scans I-IV



Long Freeze 110: 300x magnification scans I-IV

Appendix D: The Impact of Free Trade Agreements on The Ocean Spray Cooperative

THE IMPACT OF FREE TRADE AGREEMENTS ON THE OCEAN SPRAY
COOPERATIVE

A Major Qualifying Project Report:

submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

Robert Papp

Date: April 25th, 2019

Sponsoring Organization: Ocean Spray

This report represents the work of WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its website without editorial or peer review. For more information about the projects program at WPI, please see <http://www.wpi.edu/academics/ugradstudies/project-learning.html>

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Table of Contents

1.0 Introduction	52
2.0 Background	53
2.1 Ocean Spray.....	53
2.2 Tariffs.....	53
2.3 World Trade Organization.....	53
2.4 Free Trade Agreements.....	54
3.0 Literature Review	55
3.1 The Importance of Trade Relationships.....	55
3.2 Free Trade Agreements.....	55
3.2.1 US Free Trade Agreements.....	55
3.2.2 Canada Free Trade Agreements.....	56
3.2.3 Chile Free Trade Agreements.....	57
3.3 Agricultural Trade.....	58
3.3.1 Agricultural Trade in the US.....	59
3.3.2 Agricultural Trade in Canada.....	59
3.3.3 Agricultural Trade in Chile.....	60
4.0 Methodology	61
4.1 Interviews.....	61
4.2 Document Analysis.....	61
5.0 Results/Discussion	62
5.1 What does the US agricultural trade lack?.....	62
5.1.1 Where does the US not have free trade agreements?.....	62
5.1.2 Why does the US not have a free trade agreement with the EU?.....	62
5.1.3 Why does the US not have a free trade agreement with East Asia?.....	62
5.2 Canada and the EU.....	63

5.2.1 The Canada-European Free Trade Association Free Trade Agreement (CETA).....	63
5.3 Chile and China.....	63
5.3.2 Chile-China Free Trade Agreement.....	63
5.4 Ocean Spray Abroad.....	63
6.0 Conclusion.....	65
Endnotes.....	66
References.....	69

List of Tables

Table 1: US Free Trade Agreement List.....56

Table 2: Canada Free Trade Agreement List57

Table 3: Chile Free Trade Agreement List58

Table 4: Top Suppliers of Fruits and Vegetables Imported into the US (2015).....59

1.0 Introduction

International trade is a complicated and difficult system to work in and navigate through. The agricultural industry is an even more sensitive industry than most international trade, so to be an agricultural organization working on an international scale means that you will have to acknowledge many different country's rules and regulations. Free trade agreements attempt to make it easier on these companies looking to sell their product internationally. Ocean Spray is an agricultural cooperative based out of America. Ocean Spray has to work in this restricting environment of international trade. Recently, they have acquired two companies based out of Chile and Canada. My paper seeks to answer the following research questions:

- Why does Ocean Spray have farms in other countries, like Chile and Canada?
- What motivated the establishment of Ocean Spray farms outside of the US?
- Are these farms treated differently than the American-based farms by the company?

I conclude with recommendations as to how Ocean Spray can use these new acquisitions to their benefit through free trade agreements and international relationships.

2.0 Background

2.1 Ocean Spray

Ocean Spray is an agricultural cooperative based out of Massachusetts. It was formed in 1930 by a group of independent cranberry growers. This new cooperative allowed them to pull their resources and produce more products out of their cranberries. They moved from fresh cranberries to jellied cranberry sauces, cranberry juices and to Craisins[®]; (Craisins[®] are Ocean Spray's dried cranberry product). Ocean Spray has expanded massively since the 1930s. They first started with three families, but have since grown to over 700 families in North and South America.[1]

As stated above, Ocean Spray is a cooperative, not a corporation. Cooperatives follow different rules than corporations. In order to be considered a cooperative the company needs to be run with a certain framework. The cooperative needs to be controlled by the members of the cooperation. In the case of Ocean Spray, the cooperative is owned by the farmers. This means that the farmers make the decisions on what happens in the company.[2] The second condition that needs to be met is called subordination of capital. "Subordination of capital requires an organization to limit the financial return made on its equity capital,"[3] meaning that all extra revenue must be distributed amongst the patrons of the cooperation. Lastly, a cooperation must distribute revenue evenly amongst the patrons. If a company meets all of these requirements they are entitled to tax benefits and avoidance of corporate taxes.[4]

Recently Ocean Spray has acquired companies and expanded operations to Chile and Canada. In early 2013 Ocean Spray acquired CranChile located in Lanco Chile.[5] Ocean Spray also acquired Atoka based out of British Columbia, Canada.[6]

2.2 Tariffs

Having plants in three different countries forces Ocean Spray to pay attention to three different countries' sets of trade rules and regulations. One of the major parts of dealing with trade regulations is tariffs. A tariff is a tax imposed on imported goods coming into a country. This tax can be either a fixed rate or a percentage of the value of the imported product. Typically a country might impose a tariff if they want to support domestic industry growth, promote national security, or retaliate to another tariff imposed on them. Two countries can go to "war" by imposing tariffs on one another in retaliation of one another. A trade war can hinder free trade and can hurt the economies of both countries involved.[7]

2.3 World Trade Organization

The World Trade Organization (WTO) was formed in 1995 and is based out of Geneva, Switzerland. It provides several functions such as administering trade agreements, managing trade disputes and providing a council for negotiations in regards to trade.[8] The WTO is formed by 164 members including Chile, Canada and the US.[9]

2.4 Free Trade Agreements

Free trade agreements are ways that countries prioritize, organize and open trade between states. Countries that are involved in free trade agreements with one another tend to be closer allies.^[10] There are three different types of free trade agreements:

- Unilateral – When a country either tightens or loosens restrictions on trade in their country without any other country responding.
- Bilateral – When two countries make an agreement to lower tariffs between each other.
- Multilateral – When three or more countries negotiate an agreement to loosen trade restrictions amongst one another.^[11]

Most free trade agreements are bilateral agreements, but there are some multilateral agreements as well.

3.0 Literature Review

3.1 The Importance of Trade Relationships

Trade relationships between states is argued to be beneficial for all countries involved, because it provides for a higher quality of life. It allows for certain countries to specialize certain industries, “For example, the United States has specialized in the production of aircraft, industrial machinery, and agricultural commodities (particularly corn, soybeans, and wheat). In exchange for exports of these products, the United States purchases, among other things, imports of crude oil, clothing, and iron, and steel mill products.”^[12] This sort of dividing of product development amongst countries allows for certain countries to grow and focus on one or a few industries at once. This leads to higher quality products, which then lead to a higher quality of life for the countries involved.^[13]

However, there are arguments against international free trade. The main argument is that it could hurt domestic industries. For example when NAFTA was created, people believed that it would take away many jobs from US citizens.^[14]

3.2 Free Trade Agreements

Free trade agreements are formed depending on many different factors, and each state has their own reasons for forming (or not forming) free trade agreements. For the purpose of this paper, I focus on the free trade agreements involving the countries Chile, Canada, and the US.

3.2.1 US Free Trade Agreements

The US has free trade agreements across the globe, with established with countries in the Western Hemisphere (Table 1). Outside of these countries, America has a few free trade agreements in the Middle East and in Asia. It should be noted that the US does not have any free trade agreements with China, or any country in the continent of Europe.

Agreement Name	Country Involved
The U.S.-Chile Free Trade Agreement	Chile
The U.S.-Columbia Free Trade Promotion Agreement	Columbia
Dominican Republic-Central America-United States Free Trade Agreement	Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, & Nicaragua
The North American Free Trade Agreement	Canada and Mexico
The U.S.-Panama Trade Promotion Agreement	Panama
The U.S.-Peru Trade Promotion Agreement	Peru
U.S.-Bahrain Free Trade Agreement	Bahrain
The U.S.-Israel Free Trade Area Agreement	Israel
U.S.-Jordan Free Trade Agreement	Jordan
The U.S.-Oman Free Trade Agreement	Oman
The U.S.-Korea Free Trade Agreement	Korea
The U.S.-Singapore Free Trade Agreement	Singapore
The U.S.-Australia Free Trade Agreement	Australia
The U.S.-Morocco Free Trade Agreement	Morocco

Table 1: US Free Trade Agreement List[15]

3.2.2 Canada Free Trade Agreements

Canada has a few free trade agreements with major regions and countries that the US is not involved in (Table 2), though share several free trade partners with the US. The largest difference is Canada's free trade agreements with the European countries. Canada also tends to have more multilateral free trade agreements.

Agreement Name	Country Involved
Comprehensive and Progressive Agreement for Trans-Pacific Partnership	Australia, Brunei, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore & Vietnam
Canada-Costa Rica Free Trade Agreement	Costa Rica
Canada-Chile Free Trade Agreement	Chile
Canada-Columbia Free Trade Agreement	Columbia
Canada-Honduras Free Trade Agreement	Honduras
North American Free Trade Agreement	USA and Mexico
Canada-Panama Free Trade Agreement	Panama
Canada-Peru Free Trade Agreement	Peru
Canada-U.S. Free Trade Agreement	USA
Canada-Israel Free Trade Agreement	Israel
Canada-Jordan Free Trade Agreement	Jordan
Canada-Korea Free Trade Agreement	Korea
Canada-European Free Trade Association Free Trade Agreement	Iceland, Liechtenstein, Norway & Switzerland
Canada-European Union Comprehensive Economic and Trade Agreement	All countries in the European Union
Canada-Ukraine Free Trade Agreement	Ukraine

Table 2: Canada Free Trade Agreement List[16]

3.2.3 Chile Free Trade Agreements

Chile has significantly more free trade agreements than Canada and the US (Table 3), including with many regions of the world that the free trade agreements of Canada and the US do not reach. The most noticeable partnership that Chile maintains is its free trade agreement with China. Neither the US nor Canada have free trade agreements with China.

Agreement Name	Country Involved
Pacific Alliance	Colombia, Mexico & Peru
Chile-Thailand Free Trade Agreement	Thailand
Chile-Hong Kong, China Free Trade Agreement	Hong Kong and China
Chile-Vietnam Free Trade Agreement	Vietnam
Chile-Malaysia Free Trade Agreement	Malaysia
Chile-Turkey Free Trade Agreement	Turkey
Chile-Australia Free Trade Agreement	Australia
Japan and Chile for a Strategic Economic Partnership	Japan
Chile-Colombia Free Trade Agreement	Colombia
Chile-Peru Free Trade Agreement	Peru
Chile-Panama Free Trade Agreement	Panama
Chile-China Free Trade Agreement	China
Trans-Pacific Strategic Economic Partnership	Brunei, Singapore & New Zealand
Chile-EFTA Free Trade Agreement	Iceland, Liechtenstein, Norway & Switzerland
Chile-EU Free Trade Agreement	Entire EU
Chile-U.S. Free Trade Agreement	USA
Chile-Korea Free Trade Agreement	Korea
Free Trade Agreement between Central America and Chile	Costa Rica, El Salvador, Guatemala, Honduras & Nicaragua
Chile-Mexico Free Trade Agreement	Mexico
Canada-Chile Free Trade Agreement	Canada
Free Trade Agreement between Chile and MERCOSUR	Argentina, Brazil, Paraguay & Uruguay

Table 3: Chile Free Trade Agreement List[17]

3.3 Agricultural Trade

3.3.1 Agricultural Trade in the US

In recent years the US has had a growing trade deficit when it comes to agricultural trade. In 2015, the US exported a total of \$6.3 billion in fruit and vegetables and imported \$17.3 billion.[18] This is a gap of \$11.4 billion. The US largely imports its fruits and vegetables from the Americas.

Country	% of 2015 US Imports
Mexico	44%
Canada	12%
Chile	8%
EU-28	7%
China	6%
Peru	5%
Costa Rica	3%
Guatemala	2%
Thailand	2%
Brazil	2%

Table 4: Top Suppliers of Fruits and Vegetables Imported into the US (2015)[19]

As noted above, the country with the largest percentage of US agricultural imports in 2015 is Mexico with 44%. Of this list, the EU, China, and Thailand do not have any free trade agreements with the US. This means that they do not get priority treatment that the other countries on this list get from the US. The EU still makes it in this list because of the fact that farming in the EU is highly subsidized by the government. This makes it cheaper for farmers to sell their product to the US.[20]

3.3.2 Agricultural Trade in Canada

In terms of agriculture, Canada has strong trade relations with the US. In 2017 the US exported 17% of its agricultural exports to Canada. Canada is also looking to expand their agriculture and food market and reach, “On April 1st 2018, the Government of Canada launched the Canadian Agricultural Partnership - a progressive \$3 billion commitment that will help chart the course for government investments in the sector over the next five years.”[21] This will allow Canada to expand their market size.

In 2017, Canada signed a new free trade agreement with the European Union that makes about 94% of all Canadian agriculture going to the EU duty free.[22] This free trade agreement looks to eliminate all tariffs between the parties after 8 years of the agreement being signed.[23] Besides its free trade agreements with the US and EU, Canada also signed a number of free trade agreements with countries that the US does not have free trade agreements with.

3.3.3 Agricultural Trade in Chile

As Chile is a smaller country than the US and Canada, it relies more on trade to survive and acquire the resources they need. Agriculture is one of the major industries in the Chile and a major part of their trade, “The agriculture industry is responsible for 28% of total Chilean trade, as well as 11% of its total GDP. Twenty percent of Chile’s labor force is engaged in agriculture.”[24] To support all of this trade Chile has signed many free trade agreements. Many of the free trade agreements have been signed in recent years. In 2017, Chile signed 21 new free trade agreements.[25]

4.0 Methodology

4.1 Interviews

Mr. Jay Glidden was interviewed for his knowledge of agricultural trade in Chile, Canada, and the US and how it applies to Ocean Spray as a company. Mr. Glidden is a Customs and Trade Compliance Analyst at Ocean Spray. The interview with Mr. Glidden provided insight into the reasoning behind Ocean Spray's corporate decision-making. The interview provided information with regard to the free trade agreements that most apply to Ocean Spray.

4.2 Document Analysis

In addition to interviewing Mr. Glidden, I analyzed documents to give context and background to Ocean Spray's position as a company navigating the global market. Research was focused around US's, Chile's, and Canada's agricultural trade, and their respective free trade agreements. These free trade agreements were then examined in conjunction with the overall agricultural trade of each country to determine the best way for Ocean Spray to move forward with these state's free trade agreements.

5.0 Results/Discussion

5.1 What does the US agricultural trade lack?

5.1.1 Where does the US not have free trade agreements?

In comparison to many developed countries the US has fewer free trade agreements. When reviewing American trade, there are two major regions of the world with which the US has not established free trade agreements: European Union member states (either individually or as a whole) and East Asian states.

5.1.2 Why does the US not have a free trade agreement with the EU?

The US currently does not have any free trade agreements with the EU. This is due to the failure of the Transatlantic Trade and Investment Partnership (T-TIP) negotiations in 2017. T-TIP negotiations were launched during the Obama Administration in 2013, and the partnership would have been one of the largest free trade agreements in the world if it had been signed and put into force.[26]

However, agreement on agricultural issues was significant obstacle for T-TIP negotiations. The US and EU have very different standards when it comes to genetically-modified foods. The EU refuses to allow any of their meat be treated with any sort of growth hormones. While in the US growth hormones in meats and other genetically-modified foods are very prevalent. Another, smaller, agricultural issue that came up during negotiations was the fact that the EU does not allow for chicken to be washed with chlorine for sanitation issues, while this is common practice in the US.[27] The only way for the negotiations to be completed would be if either party compromised on these points.[28] The last round of negotiations was in early October 2016.[29] In 2017, President Trump adjourned these negotiations.[30]

5.1.3 Why does the US not have a free trade agreement with East Asia?

In East Asia, the major country with whom the US lacks a free trade agreement is China. At the moment, the US and China are in a trade war. The US and China have been tense when it comes to trade relations since the Obama Administration. However, the most recent issue between China and the US has been both military and trade related.[31]

China has been building artificial islands in the South China Sea and claiming them as their own territory. On the military side, this is an issue because it allows for China to have strategic positioning in the South China Sea without having a carrier there. More importantly though is the trade issues that come with the construction of these artificial islands. With these artificial islands comes new territorial waters.[32] Any country that owns islands or coastal waters also claims 12 nautical miles of territorial waters from the baseline of that land.[33] This means that China is able to restrict ships from travelling through those waters and threaten free trade around the world.

With this issue in the mind of the US government, they have decided to take a number of actions to stop China. The main action, pertaining to the topic of trade, is to raise tariffs on

China. China has responded with raising tariffs on the US, and soon a trade war starts to form as both countries continue to raise tariffs.[34]

5.2 Canada and the EU.

5.2.1 The Canada-European Free Trade Association Free Trade Agreement (CETA)

CETA is a free trade agreement that has been signed between Canada and the European Union. The agreement was signed in October 2016 and put into force in September 2017.[35] The EU is the second largest market in the world, which has made this agreement massively beneficial to Canada. “Prior to CETA’s entry into force, only 25 percent of EU tariff lines on Canadian goods were duty-free. With CETA, 98 percent of EU tariff lines are now duty-free for Canadian goods. Once CETA is fully implemented, the EU will have eliminated tariffs on 99 percent of its tariff lines.”[36] When it comes to agriculture, most of Canada’s agriculture is duty free under this free trade agreement, including “Sweet Dried Cranberries”.[37]

5.3 Chile and China.

5.3.2 Chile-China Free Trade Agreement

China has been expanding their trade, and has been showing interest in Latin American countries.[38] China has turned to countries like Chile for natural resources with promises of free trade with China, with Chile being the first Latin American state to sign a free trade agreement with China. After signing this treaty, Chile supported China in becoming a member of the WTO and was quick to recognize them as a free market economy.[39] The Chile-China Free Trade Agreement was signed in November 2005 in South Korea.[40] The agreement set up a timeframe to remove tariffs over the course of either immediately, five or ten years. For agricultural products the free trade agreement had both parties lower their farm subsidies, so as to not dramatically raise prices of agricultural products.[41]

5.4 Ocean Spray Abroad

How should Ocean Spray use these free trade agreements to put them in a better position? When looking at the free trade agreements that the US is signed onto, from the literature review, it can be seen that the US is lacking free trade agreements with the countries of Europe, and Asia, specifically China. This makes it hard for Ocean Spray to compete with other companies in these regions. However, when looking at the new additions of the plants in Chile and Canada, we can see how Ocean Spray can use these plants for international trade that is more advantageous to Ocean Spray.

Ocean Spray can use their position in Canada to use the Canada-European Free Trade Association Free Trade Agreement (CETA) that Canada is signed onto. Under this free trade agreement Ocean Spray would be able to take advantage of the duty free product. In fact, about 95% of all agricultural product being exported out of Canada into the EU is duty-free.[42] Ocean Spray can use this free trade agreement to avoid some of the duties that companies shipping agricultural product to the EU from the US might face.

Ocean Spray can use their position in Chile to benefit them in a few different ways. First, Ocean Spray can use their farms in Chile as a reciprocal growing season when the growing season in the Northern regions are in their offseason.^[43] Secondly, Ocean Spray can use the Chile-China Free Trade Agreement to sell their product to China with little to no duty.^[44]

6.0 Conclusion

Agricultural trade on an international scale is difficult and can be expensive for many companies to deal with. However, Ocean Spray can put themselves in a good position by using their plants in Chile and Canada to avoid tariffs placed on the US from countries.

Ocean Spray's farms in Canada and Chile offer other benefits than just more product production to the company. It is recommended that Ocean Spray use these countries' free trade agreements to avoid paying duties on products to be exported from the US. The US lacks free trade agreements with major regions of the world: Asia, China specifically, and Europe. By looking at the free trade agreements in Canada it can be seen that Ocean Spray can use their position in the country to take advantage of the CETA agreement. Ocean Spray can use their location in Chile for two different benefits. The farms can be used for a reciprocal growing season to Northern plants. Secondly, Ocean Spray can use the Chile-China Free Trade Agreement that Chile is signed onto to sell product to China without dealing with the duties they would have to pay if they were selling from the US.

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