

# **pH and Probiotics: Is Traditional Yogurt Better?**

Anika Sharma Fergusson  
Summit Middle School  
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## **Abstract**

Yogurt contains probiotic bacteria, which are similar to the naturally-occurring, beneficial bacteria in the human intestine. This results in the health benefits which have been attributed to yogurt for centuries. In order to create yogurt, the bacteria convert the lactose in milk into lactic acid. Therefore, the pH of yogurt can be measured to indirectly observe the relative amount of probiotic bacteria in a given sample of yogurt. Many commercial brands of yogurt advertise live-and-active cultures, however the brands have not been independently compared to see which brand has the highest amount of probiotics. This study compared pH values to infer probiotic activity in 5 supermarket brands of yogurt (Chobani, Wallaby, Strauss, Siggi's and White Mountain). White Mountain had a mean pH value of 3.67, whereas all other brands were clustered between 4.02 and 4.26 on the pH scale. The fermentation rate (pH decrease over the 5 weeks) of White Mountain was 0.0245, whereas the other fermentation rates were all below 0.016. Statistical analyses revealed that these differences were significant, showing that White Mountain was significantly higher in terms of fermentation rate and overall acidity. White Mountain is a brand of Bulgarian traditional yogurt, and since it gave detailed information about the traditional production methods while other yogurt brands simply stated that they were based on, for example, Greek or Icelandic tradition, White Mountain can be considered the most traditional yogurt out of the five brands. This suggests that traditional production methods positively influence probiotic activity.

## **Introduction**

Over the years, many people have been cured of diseases through ingestion of yogurt and fermented milk, including King Francis I of France. Recent studies have attributed this to the fact that yogurt and fermented milk are beneficial for the overall health of the intestine (Shah 327, Mazahreh 3, Ringel-Kulka 1). Yogurt sales are very high in the U.S.A., mainly because yogurt is considered a healthy food. There are many yogurt brands sold in supermarkets. However, there is very little information comparing the different brands of yogurts and how each brand might affect human health, apart from the claims made by the companies themselves.

Yogurt's health benefits occur because there is probiotic, lactic acid bacteria in the yogurt similar to the bacteria in the human intestine. In fact, according to the Food and Drug Administration (FDA), the definition of yogurt is "the food produced by culturing one or more... dairy ingredients... with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus*" (FDA). The two main strains of probiotic bacteria in yogurt are the aforementioned *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, although other strains may also be added. (Adolfsson 1, FDA). These bacterial cultures react with the lactose in milk to produce lactic acid, decreasing the yogurt's pH (Sorenson 2). A lower pH in the yogurt means a greater acidity in the yogurt, inferring greater probiotic activity. A higher fermentation rate means that the yogurt is becoming more acidic (fermenting) faster. Therefore, pH can be measured to infer the relative amount and efficiency of the probiotic bacteria in the yogurt, which can in turn predict the beneficial effect it can have on the human intestine.

There are many different production styles of yogurt which usually represent different yogurt producing countries. For example, brands of Greek yogurt are very popular today but there are other yogurts brands in the market which use other production methods like Bulgarian and Icelandic methods. Different brands of yogurt have varying amounts and strains of probiotic bacteria, along with different production methods. Traditional production methods for yogurt have been perfected over hundreds of years. Bulgarian yogurt and Greek yogurt have been produced the longest. In fact, Bulgarian people have historically been known for their longevity, which has been attributed to the considerable presence that yogurt has had in their diet (Metchnikoff 170). Therefore, different production methods and styles may contribute to probiotic efficiency in yogurt, which may influence human health.

## **Aim**

The aim of this study was to determine which commercial yogurt brand out of the five tested (Chobani, Wallaby, Straus, Siggi's, and White Mountain) is the most beneficial to the human intestine based on the overall acidity and fermentation rate of each brand of yogurt.

## **Hypothesis**

Five supermarket yogurt brands (Chobani, Straus, Wallaby, White Mountain, and Siggi's) were tested for pH. Each yogurt brand was expected to have a different overall acidity and fermentation rate. The brands using the most traditional production methods (e.g. White Mountain) were expected to have the highest fermentation rate and overall acidity suggesting that traditional methods yield the greatest number of and most efficient probiotic bacteria.

## Materials and Methods

For the experiment, the pH of five brands of yogurt (Chobani, Wallaby, Straus, White Mountain, and Siggi's) were tested. These yogurts were purchased from supermarkets such as King Soopers and Whole Foods. The 5 yogurts chosen had similar expiration dates. The pH was tested using a pH meter from Milwaukee Instruments, model MW102. The electrode used with the pH meter was model MA920B/1, which was specialized for use with dairy products. The pH meter was calibrated according to the information enclosed with the meter, which included using provided calibration solutions with known pH values to calibrate the meter to the correct readings.

After calibration, pH readings were measured for each yogurt. The pH was carefully measured ten times per brand. Between each trial, the pH electrode was rinsed with filtered water to remove excess yogurt, and between each yogurt measurement the pH electrode was rinsed with filtered water for accurate readings. The aforementioned measurement process was repeated three weeks before the expiration date, two weeks before the expiration date, one week before the expiration date, on the expiration date, and one week after the expiration date of each yogurt brand.

Figure 1 shows the materials used (including the pH meter and the electrode). Figure 2 shows the calibration process in progress. Figure 3 shows the pH measurement in progress for the Chobani brand of yogurt.

Descriptive statistics (average, min, max, and standard deviation), were calculated for each set of 10 trials per yogurt. Graphs were created showing the relationship of pH and expiration date for each yogurt brand. The fermentation rate of the yogurt was calculated by taking the opposite of the slope of each line on the line graph. One way ANOVAs and repeated measures t-tests were performed on the data. Conclusions were formulated based on the results.



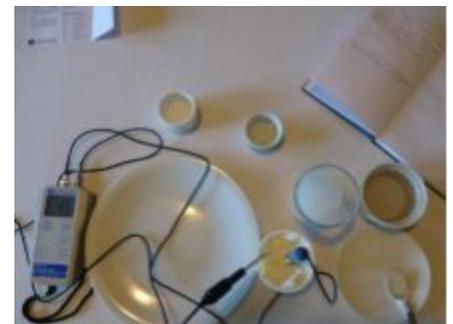
Image of Materials Required

*Figure 1*



Image of Calibration Process

*Figure 2*



Testing the acidity of the Chobani yogurt

*Figure 3*

## Results and Data Analysis

The different brands of yogurt had different strains of probiotics. These are shown in Table 1. Straus and White Mountain had fewer strains than Wallaby, Chobani and Siggi's.

### A. List of Probiotic Strains per yogurt brand

	Strains	Number of Total Strains
Wallaby	<i>L. Acidophilus</i> , <i>L. Bulgaricus</i> , <i>S. Thermophilus</i> , <i>Bifidus</i> , <i>L. Paracasei</i>	5
Chobani	<i>S. Thermophilus</i> , <i>L. Bulgaricus</i> , <i>L. Acidophilus</i> , <i>Bifidus</i> , <i>L. Casei</i>	5
Siggi's	<i>S. Thermophilus</i> , <i>L. Bulgaricus</i> , <i>B. Lactis</i> , <i>L. Acidophilus</i> , <i>L. Lactis</i>	5
Straus	<i>L. Acidophilus</i> , <i>L. Bulgaricus</i> , <i>S. Thermophilus</i> , <i>Bifidobacterium Lactis</i>	4
White Mountain	<i>L. Acidophilus</i> , <i>L. Bulgaricus</i> , <i>S. Thermophilus</i> , <i>B. Bifidum</i>	4

Table 1, list and total number of probiotic strains per yogurt brand. This information was provided on the yogurt containers.

### B. Statistical Analysis

#### 1. Analysis of Variance (ANOVA)

The graph below shows mean yogurt pH values at each time increment.

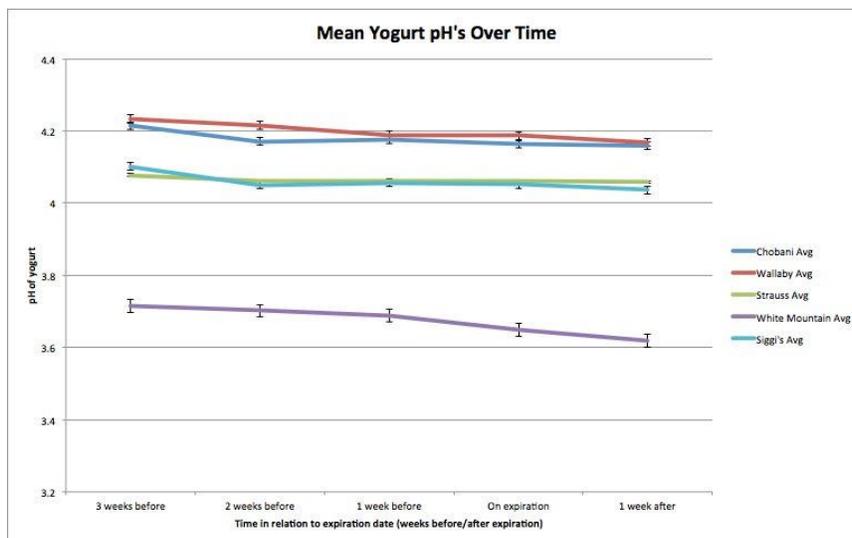


Figure 4, graph of mean yogurt pH values over time. Standard error bars are shown.

One-way Analyses of Variance (ANOVAs) were performed to compare yogurt pH for each brand at each time increment in relation to the expiration date. The F statistic values are shown in Table 2. The corresponding p-values were significant at  $p < 0.01$  showing a main effect for yogurt brand. Post-hoc t-tests (using the Bonferroni correction) showed significant differences ( $p < 0.001$ ) for all yogurt brand comparisons at every time increment (except for Chobani vs. Wallaby at 3 weeks before, 1 week before, and 1 week after the expiration date, and for Straus vs Siggi's at 3 weeks before, 2 weeks before, 1 week before the expiration date, and on the expiration date). See Appendix B for details on the post-hoc comparisons. Overall, the results of the ANOVA and post-hoc t-tests show that the White Mountain brand had a significantly lower pH in comparison to the other brands.

Summary of Means and ANOVA results

	<i>Chobani</i>	<i>Wallaby</i>	<i>Strauss</i>	<i>White</i> <i>Mountain</i>	<i>Siggi's</i>	<i>F statistic</i>	<i>P value</i> <i>(scientific notation)</i>
	<i>Avg</i>	<i>Avg</i>	<i>Avg</i>	<i>Avg</i>	<i>Avg</i>		
<i>3 weeks before</i>	4.214	4.233	4.078	3.715	4.102	1360.66	$1.11 \times 10^{-16}$
<i>2 weeks before</i>	4.171	4.216	4.061	3.702	4.051	554.31	$1.11 \times 10^{-16}$
<i>1 week before</i>	4.175	4.189	4.061	3.689	4.057	1898.38	$1.11 \times 10^{-16}$
<i>On expiration</i>	4.163	4.187	4.061	3.649	4.052	2368.72	$1.11 \times 10^{-16}$
<i>1 week after</i>	4.159	4.168	4.059	3.619	4.036	5351.17	$1.11 \times 10^{-16}$

Table 2, table of yogurt pH means with F statistic and P Value

## 2. Repeated Measures t-tests

For each yogurt brand, the pH values at the earliest and latest time increments (i.e., 3 weeks before expiration and 1 week after expiration) were compared to determine if there was a significant change in the pH over time. Results of repeated measures t-tests are shown in Table 3. As can be seen, all brands showed a significant change in pH over 5 weeks.

	<i>3 weeks before</i>	<i>1 week before</i>	<i>P Value for Repeated Measures T-Test</i>
<i>Chobani</i>	<i>4.214</i>	<i>4.159</i>	<i>0.000005729022508</i>
<i>Wallaby</i>	<i>4.233</i>	<i>4.168</i>	<i>0.000000781698239</i>
<i>Straus</i>	<i>4.078</i>	<i>4.059</i>	<i>0.008483787616</i>
<i>White Mountain</i>	<i>3.715</i>	<i>3.619</i>	<i>0.000001801209965</i>
<i>Siggi's</i>	<i>4.102</i>	<i>4.036</i>	<i>0.0000003341015973</i>

Table 3, Repeated measures t-tests (p-value shown) of 3 weeks before & 1 week after for each yogurt brand

## 3. Fermentation Rate

For each yogurt brand the fermentation rate (change in pH over 5 weeks) was calculated using the equation:

$$r = -(y-b)/x$$

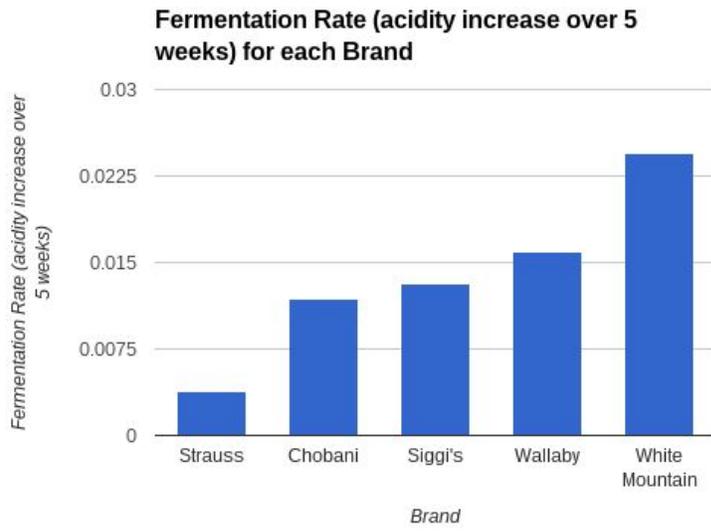
Where  $r$ =fermentation rate

The equation is an altered form of the general equation of a line,  $y=mx+b$  where  $m$ =slope of the line.

As the fermentation rate is simply the opposite (negative) of the slope, the equation was rearranged to be in terms of the slope, and then was reversed to be the opposite.

<i>Brand</i>	<i>Fermentation Rate (acidity increase over 5 weeks)</i>
<i>Chobani</i>	<i>0.0118</i>
<i>Wallaby</i>	<i>0.0159</i>
<i>Straus</i>	<i>0.0038</i>
<i>White Mountain</i>	<i>0.0245</i>
<i>Siggi's</i>	<i>0.0131</i>

Table 4, fermentation rates for each yogurt brand.



*Figure 5, graph of fermentation rate for each yogurt brand*

As seen in Figure 5, White Mountain yogurt had the highest fermentation rate (0.0245), while all the other yogurts had fermentation rates below 0.016.

Overall, the results show that White Mountain yogurt had the significantly lowest pH (i.e., highest acidity) and significantly highest fermentation rate suggesting the most probiotic activity.

## Discussion

This study was done to compare pH values across 5 brands of supermarket yogurt (Chobani, Wallaby, Strauss, Siggi's and White Mountain) to see which one has the most efficient probiotic bacteria.

The White Mountain brand (Bulgarian yogurt) had a significantly higher overall acidity (pH between 3.6 and 3.8) and fermentation rate (0.0245 acidity increase over the five weeks) than the other yogurt brands (as shown in figs. 4 and 5, and tables 2, 3 and 4). The other four yogurt brands (Chobani, Siggi's, Wallaby and Straus) were clustered together on the pH scale and in terms of fermentation rate. Straus had the lowest fermentation rate, and Wallaby had the lowest overall acidity (i.e. highest pH).

The above results were based on one way ANOVAs performed to compare yogurt pH values for each brand at each time increment (3 weeks before, 2 weeks before, 1 week before, at expiration and one week after). The ANOVAs showed a main effect of yogurt brand at every time increment (Table 2). Post hoc t-tests (with Bonferroni correction) showed that White Mountain had a significantly lower pH value compared to all the other brands at all time increments (Figure 4).

Repeated measures t-tests were done to compare pH values 3 weeks before expiration and 1 week after expiration for each brand. As seen in Table 3, all yogurts showed significant differences across these time points, suggesting that the starting and ending pH values were significantly different for each yogurt brand. Slopes were calculated to determine the change in pH over the 5 week increment. The opposite (negative) of the slope of each line in Fig. 4 was calculated to find the fermentation rate of each yogurt. As seen in Figure 5, White Mountain had the highest fermentation rate (0.0245), whereas the other fermentation rates were all  $<0.016$ .

Since the White Mountain brand had a significantly higher overall acidity *and* a significantly higher fermentation rate than the other brands, it can be inferred that there are a higher number of and/or more efficient probiotic bacteria in the yogurt. It can be deduced that White Mountain can be considered the most traditional among the five brands tested. The other brands only published vague or no information about how their production methods are traditional, and they simply stated that they were based on, for example, Greek or Icelandic tradition (Chobani, "Siggi's Icelandic Yogurt - skyr", Wallaby Organic Yogurt, Straus Family Creamery). On the other hand, White Mountain outlined its traditional Bulgarian production style in a very detailed manner. For example, it specified a 24 hour fermentation period and traditional blend of cultures (White Mountain Traditional Bulgarian Yogurt). Overall, it can be

deduced, that the traditional production methods used to make the White Mountain yogurt are the most effective in terms of ensuring the highest probiotic activity. White Mountain had a lower number of probiotic strains when compared to the other brands (Table 1), and this shows that the number of strains has no significant effect on the amount of probiotics in the yogurt.

The Wallaby brand of Greek yogurt had the lowest overall acidity, its pH having been  $>4.15$  at all time increments. Wallaby gave the *least* amount of information on the production processes, showing that it can be considered the least traditional among the five brands of yogurt and that the less traditional the style, the less efficient the probiotic activity.

### **Statement of Confidence in the Data**

The low variability reflected by the standard error bars in Fig. 4 and standard deviations (Appendix A) suggests that the experiment was tightly controlled. The significance shown by the low  $p$  values, suggests that the confidence is high for results of the study.

### **Limitations**

Limitations of the study included (a) that only 5 brands of yogurt were tested and so the results may not apply to other yogurt brands available in supermarkets, and since only plain yogurts were used the results may or may not apply to flavored yogurts, and (b) that other techniques using microscopes can be used to observe probiotic activity, but this requires very powerful microscopes which were not available. However, other studies (Farnsworth 4) suggest that pH is a valid means of inferring probiotic activity.

### **Comparison to Similar Studies**

A similar study is that of “Growth of Probiotic Bacteria and Bifidobacterium in a Soy Yogurt Formulation.” This study shows that the fermentation rates in cow’s milk and soy yogurt formulations are starkly different. However, the important comparison that can be drawn to this study is that the fermentation rates and pH changes of cow’s milk yogurt in this study were reasonable when compared to those in the other study (Farnsworth 4).

The study also indicated that pH values are a valid measure of probiotic activity in yogurt.

There were no other similar publically available studies that were found.

### **Next Steps**

Given that a commercial but traditionally made yogurt had the highest overall acidity and fermentation rate, and therefore most probiotic activity, a continuation of this experiment could include homemade yogurt. pH measurements of homemade yogurt could be very interesting because the fermentation rates would most likely be steeper. This would be because homemade yogurt is generally given more time to ferment in room temperature air before being put in a refrigerator or another method of cooling the yogurt.

Additionally, for greater variety and a larger sample size, yogurt from other brands (such as Noosa or Yoplait) using additional production styles (Australian, American, etc.) could be compared.

## **Conclusions**

It is concluded that White Mountain Bulgarian yogurt had the highest overall pH *and* the highest fermentation rate out of the five brands of live-and-active-culture yogurt (see fig. 4 and 5, tables 2, 3 and 4). White Mountain can be considered the most traditional out of the five brands, as it uses traditional Bulgarian production methods as outlined on their website (White Mountain Traditional Bulgarian Yogurt), and this may show that traditional production methods have a beneficial effect on the overall acidity and fermentation rate, and therefore have the greatest amount of probiotic activity. Bulgarian people have historically been known for their longevity, which is attributed to the fact that yogurt has been a substantial part of their diet in the past (Metchnikoff 170).

This information, along with the results of the experiment, shows that White Mountain Bulgarian yogurt has the highest probiotic activity (comprised of overall pH and fermentation rate), likely because of its traditional production methods.

## **Acknowledgments**

Milwaukee Instruments was the company from which the pH meter and electrode were acquired, which was invaluable to the experiment; the experiment could not have been performed without them. Michael Teasdale and Valerie Keeney, teachers at Summit Middle School, provided assistance with writing the paper and board. Adam Perkins, the biology teacher from Summit Middle School assisted greatly with parts of the project. My parents were also extremely helpful to the project as they paid for the equipment and samples. The yogurt brands Chobani, Wallaby, Straus, White Mountain, and Siggi's were the five yogurt brands tested, and therefore were extremely valuable to the project.

## MLA Citations

Adolfsson, Oskar, Simin Nikbin Meydani, and Robert M. Russell. "Yogurt and Gut Function."

*The*

*American Journal of Clinical Nutrition* 80.2 (2004): 1-12. *The American Journal of Clinical Nutrition*. 12 Feb. 2004. Web. 4 Aug. 2016.

"Chobani." *Chobani Yogurt*. N.p., 2017. Web. 22 Jan. 2017.

Farnworth, E. R., I. Mainville, M.-P. Desjardins, N. Gardner, I. Fliss, and C. Champagne.

"Growth of Probiotic Bacteria and Bifidobacteria in a Soy Yogurt Formulation."

*International Journal of Food Microbiology* 116.1 (2007): 174-81. Academia. Web. 13 Aug. 2016.

"FDA - Code of Federal Regulations - Title 21 - Yogurt." *CFR*. FDA, 1 Apr. 2016. Web. 22 Jan. 2017.

Mazahreh, Ayman Suliman, and Omer Turki Mamdoh Ershidat. "The Benefits of Lactic Acid Bacteria in

Yogurt on the Gastrointestinal Function and Health." *Pakistan Journal of Nutrition* 8.9 (2009): 1

404-410. *Pak. J. Nutr.* Web. 14 Aug. 2016.

Metchnikoff, Elie. *The Prolongation of Life*. New York: Putnam, 1908. Print.

"Our Greek Heritage." *FAGE USA*. Fage, 2016. Web. 18 Sept. 2016.

Ringel-Kulka, Tamar, Jonathan B. Kotch, Elizabeth T. Jensen, Eric Savage, and David J. Weber.

- "Randomized, Double-Blind, Placebo-Controlled Study of Synbiotic Yogurt Effect on the Health of Children." *The Journal of Pediatrics* 166.6 (2009): 1475-481. ScienceDirect. Web. 17 Aug. 2016.
- Shah, Nagendra P. "Health Benefits of Yogurt and Fermented Milks." *Manufacturing Yogurt and Fermented Milks*. By Ramesh C. Chandan. Ed. Charles H. White, Arun Kilara, and Y. H. Hui. Carlton, Australia: Blackwell, n.d. 1-359. Google Books. Web. 12 Aug. 2016.
- "Siggi's Icelandic-style yogurt: skyr ." *Siggi's dairy*. N.p., n.d. Web. 22 Jan. 2017.
- Sorensen, Kim I., Mirjana Curic-Bawden, Mette P. Junge, Thomas Janzen, and Eric Johansen. "Enhancing the Sweetness of Yoghurt through Metabolic Remodeling of Carbohydrate." *Applied Environmental Microbiology* 82.17 (n.d.): 1-37. Applied and Environmental Microbiology. American Society for Microbiology, 22 Apr. 2016. Web. 6 Aug. 2016.
- "Straus Family Creamery - Our Yogurt." *Straus Family Creamery*. N.p., 2017. Web. 22 Jan. 2017.
- "Wallaby Organic Yogurt." *Wallaby Yogurt*. N.p., 2016. Web. 22 Jan. 2017.
- "White Mountain Foods Pure All Natural Bulgarian Yogurt Traditional 24-hr Fermentation 2 Ingredients." *White Mountain Foods Pure All Natural Bulgarian Yogurt Traditional 24-hr Fermentation 2 Ingredients*. N.p., n.d. Web. 15 Jan. 2017.

#### **Image Citations:**

- Chobani-logo-fullColor*. Digital image. *Coupon Clippers*. N.p., n.d. Web. 22 Jan. 2017.
- Political Map of Europe*. Digital image. *Map Info*. N.p., June 2012. Web. 22 Jan. 2017.
- Siggi's Plain Yogurt. Digital image. *Siggi's Icelandic Yogurt*. Siggi's, 2017. Web. 22 Jan. 2017.

Straus yogurt. Digital image. *Straus Family Creamery*. Straus, 2017. Web. 22 Jan. 2017.

Vertolli, Michael. *Lactobacillus\_bulgaricus*. Digital image. N.p., 8 Jan. 2013. Web. 22 Jan. 2017.

*Wallaby Yogurt Plain*. Digital image. *Wallaby Yogurt*. Wallaby, 2016. Web. 22 Jan. 2017.

*White Mountain Logo*. Digital image. *White Mountain Foods*. White Mtn, 2017. Web. 22 Jan. 2017.

## Appendices

### Appendix A: Raw Data

The tables below show all pH measurements taken for each yogurt brand at each time increment, along with descriptive statistics.

Greek Yogurt (Chobani)									
3 weeks before	2 weeks before		1 week before		On expiration	1 week after			
Trial 1	4.19	Trial 1	4.18	Trial 1	4.17	Trial 1	4.15	Trial 1	4.16
Trial 2	4.21	Trial 2	4.19	Trial 2	4.19	Trial 2	4.16	Trial 2	4.15
Trial 3	4.23	Trial 3	4.16	Trial 3	4.17	Trial 3	4.17	Trial 3	4.16
Trial 4	4.23	Trial 4	4.16	Trial 4	4.15	Trial 4	4.16	Trial 4	4.16
Trial 5	4.21	Trial 5	4.16	Trial 5	4.17	Trial 5	4.17	Trial 5	4.17
Trial 6	4.23	Trial 6	4.17	Trial 6	4.21	Trial 6	4.17	Trial 6	4.15
Trial 7	4.19	Trial 7	4.16	Trial 7	4.19	Trial 7	4.17	Trial 7	4.16
Trial 8	4.2	Trial 8	4.17	Trial 8	4.14	Trial 8	4.16	Trial 8	4.16
Trial 9	4.23	Trial 9	4.19	Trial 9	4.19	Trial 9	4.15	Trial 9	4.17
Trial 10	4.22	Trial 10	4.17	Trial 10	4.17	Trial 10	4.17	Trial 10	4.15
Avg	4.214		4.171		4.175		4.163		4.159
Min	4.19		4.16		4.14		4.15		4.15
Max	4.23		4.19		4.21		4.17		4.17
STDev	0.0164		0.0119		0.0206		0.0082		0.007

Table 5, pH values for the Chobani brand of Greek yogurt, including all of the pH trials for all of the time increments and simple descriptive statistics.

Greek Yogurt (Wallaby)									
3 weeks before	2 weeks before		1 week before		On expiration	1 week after			
Trial 1	4.23	Trial 1	4.17	Trial 1	4.19	Trial 1	4.21	Trial 1	4.17
Trial 2	4.26	Trial 2	4.21	Trial 2	4.18	Trial 2	4.19	Trial 2	4.19
Trial 3	4.23	Trial 3	4.23	Trial 3	4.18	Trial 3	4.2	Trial 3	4.15
Trial 4	4.25	Trial 4	4.2	Trial 4	4.19	Trial 4	4.21	Trial 4	4.16
Trial 5	4.23	Trial 5	4.21	Trial 5	4.2	Trial 5	4.16	Trial 5	4.17
Trial 6	4.23	Trial 6	4.22	Trial 6	4.19	Trial 6	4.18	Trial 6	4.17
Trial 7	4.19	Trial 7	4.23	Trial 7	4.19	Trial 7	4.21	Trial 7	4.16
Trial 8	4.23	Trial 8	4.21	Trial 8	4.18	Trial 8	4.18	Trial 8	4.18
Trial 9	4.25	Trial 9	4.25	Trial 9	4.19	Trial 9	4.16	Trial 9	4.17
Trial 10	4.23	Trial 10	4.23	Trial 10	4.2	Trial 10	4.17	Trial 10	4.16
Avg	4.233		4.216		4.189		4.187		4.168
Min	4.19		4.17		4.18		4.16		4.15
Max	4.26		4.25		4.2		4.21		4.19
STDev	0.0188		0.0217		0.0073		0.020		0.011

Table 6, pH values for the Wallaby brand of Greek yogurt, including all of the pH trials for all of the time increments and simple descriptive statistics.

European Yogurt (Strauss)							
3 weeks before	2 weeks before		1 week before		On expiration	1 week after	
Trial 1	4.05	Trial 1	4.02	Trial 1	4.07	Trial 1	4.06
Trial 2	4.12	Trial 2	4.07	Trial 2	4.06	Trial 2	4.07
Trial 3	4.09	Trial 3	4.07	Trial 3	4.05	Trial 3	4.05
Trial 4	4.07	Trial 4	4.05	Trial 4	4.07	Trial 4	4.06
Trial 5	4.08	Trial 5	4.08	Trial 5	4.05	Trial 5	4.07
Trial 6	4.08	Trial 6	4.07	Trial 6	4.06	Trial 6	4.07
Trial 7	4.09	Trial 7	4.08	Trial 7	4.06	Trial 7	4.06
Trial 8	4.06	Trial 8	4.08	Trial 8	4.06	Trial 8	4.06
Trial 9	4.07	Trial 9	4.03	Trial 9	4.07	Trial 9	4.05
Trial 10	4.07	Trial 10	4.06	Trial 10	4.06	Trial 10	4.06
Avg	4.078		4.061		4.061		4.059
Min	4.05		4.02		4.05		4.05
Max	4.12		4.08		4.07		4.07
STDev	0.01932		0.0213		0.00731		0.007

Table 7, pH values for the Straus brand of European yogurt, including all of the pH trials for all of the time increments and simple descriptive statistics.

Bulgarian Yogurt (White Mountain)							
3 weeks before	2 weeks before		1 week before		On expiration	1 week after	
Trial 1	3.7	Trial 1	3.7	Trial 1	3.72	Trial 1	3.65
Trial 2	3.68	Trial 2	3.7	Trial 2	3.69	Trial 2	3.64
Trial 3	3.73	Trial 3	3.69	Trial 3	3.7	Trial 3	3.65
Trial 4	3.72	Trial 4	3.73	Trial 4	3.68	Trial 4	3.65
Trial 5	3.69	Trial 5	3.72	Trial 5	3.68	Trial 5	3.7
Trial 6	3.72	Trial 6	3.68	Trial 6	3.65	Trial 6	3.64
Trial 7	3.75	Trial 7	3.7	Trial 7	3.68	Trial 7	3.62
Trial 8	3.73	Trial 8	3.7	Trial 8	3.71	Trial 8	3.64
Trial 9	3.72	Trial 9	3.6	Trial 9	3.68	Trial 9	3.65
Trial 10	3.71	Trial 10	3.8	Trial 10	3.7	Trial 10	3.65
Avg	3.715		3.702		3.689		3.649
Min	3.68		3.6		3.65		3.62
Max	3.75		3.8		3.72		3.7
STDev	0.02066		0.0491		0.01966		0.0202

Table 8, pH values for the White Mountain brand of Bulgarian yogurt, including all of the pH trials for all of the time increments and simple descriptive statistics.

Icelandic Yogurt (Siggis)							
3 weeks before	2 weeks before		1 week before		On expiration	1 week after	
Trial 1	4.12	Trial 1	4.07	Trial 1	4.06	Trial 1	4.04
Trial 2	4.1	Trial 2	4.05	Trial 2	4.06	Trial 2	4.05
Trial 3	4.11	Trial 3	4.02	Trial 3	4.08	Trial 3	4.06
Trial 4	4.1	Trial 4	4.05	Trial 4	4.03	Trial 4	4.05
Trial 5	4.09	Trial 5	4.05	Trial 5	4.06	Trial 5	4.06
Trial 6	4.09	Trial 6	4.06	Trial 6	4.05	Trial 6	4.06
Trial 7	4.1	Trial 7	4.05	Trial 7	4.06	Trial 7	4.06
Trial 8	4.11	Trial 8	4.04	Trial 8	4.05	Trial 8	4.05
Trial 9	4.08	Trial 9	4.06	Trial 9	4.06	Trial 9	4.05
Trial 10	4.12	Trial 10	4.06	Trial 10	4.06	Trial 10	4.04
Avg	4.102		4.051		4.057		4.052
Min	4.08		4.02		4.03		4.04
Max	4.12		4.07		4.08		4.06
STDev	0.01316		0.0137		0.01251		0.0076

Table 9, pH values for the Siggis brand of Icelandic yogurt, including all of the pH trials for all of the time increments and simple descriptive statistics.

**Appendix B: One way ANOVA and post hoc t-tests using Bonferroni corrections showing significant comparisons across the 5 yogurt brands for each time increment.**

*Comparison of 5 yogurt brands 3 weeks before expiration:*

One way ANOVA showed a significant main effect of yogurt brands ( $F=1,360.6508$ ,  $p=1.11 \times 10^{-16}$ ). Post-hoc t-tests using the Bonferroni correction showed the following results:

<i>Yogurt Brand Comparison</i>	<i>T value</i>	<i>P value</i>	<i>Significance</i>
<i>Chobani vs Wallaby</i>	2.3734	0.2195796	<i>Nonsignificant</i>
<i>Chobani vs Straus</i>	19.3616	0.000	<i>Significant</i>
<i>Chobani vs Siggis</i>	16.3636	0.000	<i>Significant</i>
<i>Chobani vs White Mountain</i>	64.7051	0.000	<i>Significant</i>
<i>Wallaby vs Straus</i>	16.9882	0.000	<i>Significant</i>
<i>Wallaby vs Siggis</i>	13.9903	0.000	<i>Significant</i>
<i>Wallaby vs White Mountain</i>	62.3317	0.000	<i>Significant</i>
<i>Straus vs Siggis</i>	2.9979	0.0441454	<i>Nonsignificant</i>
<i>Straus vs White Mountain</i>	45.3435	0.000	<i>Significant</i>
<i>Siggis vs White Mountain</i>	48.3414	0.000	<i>Significant</i>

Table 10, post-hoc t-tests 3 weeks before expiration

*Comparison of 5 yogurt brands 2 weeks before expiration:*

One way ANOVA showed a significant main effect of yogurt brands ( $F=554.3110$   $p=1.11 \times 10^{-16}$ ). Post-hoc t-tests using the Bonferroni correction showed the following results:

<i>Yogurt Brand Comparison</i>	<i>T value</i>	<i>P value</i>	<i>Significance</i>
<i>Chobani vs Wallaby</i>	3.7118	0.0056449	<i>Significant</i>
<i>Chobani vs Straus</i>	12.7852	$2.2204 \times 10^{-15}$	<i>Significant</i>
<i>Chobani vs Siggis</i>	13.6100	0.000	<i>Significant</i>
<i>Chobani vs White Mountain</i>	42.3972	0.000	<i>Significant</i>
<i>Wallaby vs Straus</i>	9.0733	$9.9860 \times 10^{-11}$	<i>Significant</i>
<i>Wallaby vs Siggis</i>	9.8982	$7.1587 \times 10^{-12}$	<i>Significant</i>
<i>Wallaby vs White Mountain</i>	38.6854	0.000	<i>Significant</i>
<i>Straus vs Siggis</i>	0.8248	4.1380879	<i>Nonsignificant</i>
<i>Straus vs White Mountain</i>	29.6121	0.000	<i>Significant</i>
<i>Siggis vs White Mountain</i>	28.7872	0.000	<i>Significant</i>

Table 11, post-hoc t-tests 2 weeks before expiration

Comparison of 5 yogurt brands 1 week before expiration:

One way ANOVA showed a significant main effect of yogurt brands ( $F=1,898.3803$ ,  $p=1.11 \times 10^{-16}$ ). Post-hoc t-tests using the Bonferroni correction showed the following results:

<b>Yogurt Brand Comparison</b>	<b>T value</b>	<b>P value</b>	<b>Significance</b>
<i>Chobani vs Wallaby</i>	2.1289	0.3876696	Nonsignificant
<i>Chobani vs Straus</i>	19.4646	0.000	Significant
<i>Chobani vs Siggis</i>	20.0728	0.000	Significant
<i>Chobani vs White Mountain</i>	76.0335	0.000	Significant
<i>Wallaby vs Straus</i>	17.3356	0.000	Significant
<i>Wallaby vs Siggis</i>	17.9439	0.000	Significant
<i>Wallaby vs White Mountain</i>	73.9045	0.000	Significant
<i>Straus vs Siggis</i>	0.6083	5.4606796	Nonsignificant
<i>Straus vs White Mountain</i>	56.5689	0.000	Significant
<i>Siggis vs White Mountain</i>	55.9606	0.000	Significant

Table 12, post-hoc t-tests 1 week before expiration

Comparison of 5 yogurt brands at expiration:

One way ANOVA showed a significant main effect of yogurt brands ( $F= 2,368.7176$ ,  $p=1.11 \times 10^{-16}$ ). Post-hoc t-tests using the Bonferroni correction showed the following results:

<b>Yogurt Brand Comparison</b>	<b>T value</b>	<b>P value</b>	<b>Significance</b>
<i>Chobani vs Wallaby</i>	3.8032	0.0042778	Significant
<i>Chobani vs Straus</i>	19.9668	0.000	Significant
<i>Chobani vs Siggis</i>	21.3930	0.000	Significant
<i>Chobani vs White Mountain</i>	85.2549	0.000	Significant
<i>Wallaby vs Straus</i>	16.1636	0.000	Significant
<i>Wallaby vs Siggis</i>	17.5898	0.000	Significant
<i>Wallaby vs White Mountain</i>	81.4517	0.000	Significant
<i>Straus vs Siggis</i>	1.4262	1.6071231	Nonsignificant
<i>Straus vs White Mountain</i>	65.2882	0.000	Significant
<i>Siggis vs White Mountain</i>	63.8620	0.000	Significant

Table 13, post-hoc t-tests on expiration

Comparison of 5 yogurt brands 1 week after expiration:

One way ANOVA showed a significant main effect of yogurt brands ( $F=5,351.1745$   $p=1.11 \times 10^{-16}$ ). Post-hoc t-tests using the Bonferroni correction showed the following results:

<b>Yogurt Brand Comparison</b>	<b>T value</b>	<b>P value</b>	<b>Significance</b>
<i>Chobani vs Wallaby</i>	2.0660	0.4461909	Nonsignificant
<i>Chobani vs Straus</i>	25.0210	0.000	Significant
<i>Chobani vs Siggis</i>	30.3006	0.000	Significant
<i>Chobani vs White Mountain</i>	126.0230	0.000	Significant
<i>Wallaby vs Straus</i>	22.9550	0.000	Significant
<i>Wallaby vs Siggis</i>	28.2347	0.000	Significant
<i>Wallaby vs White Mountain</i>	123.9570	0.000	Significant
<i>Straus vs Siggis</i>	5.2797	$3.6062 \times 10^{-5}$	Significant
<i>Straus vs White Mountain</i>	101.0020	0.000	Significant
<i>Siggis vs White Mountain</i>	95.7224	0.000	Significant

Table 14, post-hoc t-tests 1 week after expiration