Soggy Cereal

I. Introduction

Soggy cereal: one of the most disappointing sights when sifting through the pool of leftover milk in anticipation of your final few spoons of breakfast. From forgetting papers on top of your desk to chasing after your dog who escaped through a crack in the front door, many abandon their bowls of cereal during the chaos of a morning rush, only to return to indistinguishable, mushy clumps. Some justify pouring milk into the bowl before the cereal by claiming that the cereal retains its crispiness better while others try non-milk alternatives, such as coconut water, to preserve the firmness of cereal. With a focus on affordability, our group organized an investigative experiment to determine whether there is a significant difference in the distribution of Cheerios, a popular American cereal due to its inexpensive price, that become soggy when eaten with Lucerne milk versus Great Value milk, who typically has a more modest price compared to Lucerne milk.

II. Statistical Question:

Statistical Question: Is there a significant difference in the distribution of Cheerios that get soggy in Lucerne 2% milk vs. Great Value 2% milk after sitting in milk for 5 minutes?

Hypotheses

H_O: There is not a significant difference in the distribution of Cheerios that get soggy in Lucerne 2% milk vs. Great Value 2% milk after sitting in milk for 5 minutes.

H_A: There is a significant difference in the distribution of Cheerios that get soggy in Lucerne 2% milk vs. Great Value 2% milk after sitting in milk for 5 minutes.

III. Data Collection

First, sixty styrofoam bowls of identical size, material and shape were set out on the counter. To ensure that the size or texture of the bowl wasn't a confounding variable, the bowls were exactly the same. We also controlled how long the milk will be refrigerated for (24 hours before the start of the experiment), the temperature that the milk is refrigerated (37 degrees Fahrenheit), and the order of what went in the bowl first. Cereal came before the milk in every trial. There is no need to do a blind study, as all of our subjects were inanimate objects. To ensure normality, we made each of the treatment groups have 30 subjects. Although we couldn't actually know before collecting experimental data that normality would be met since we didn't know the expected counts, in using a large sample size we increased the power of the test so that there is a higher chance of us rejecting the null hypothesis when it is false. A larger sample size also reduced variability by chance among bowls, making our data more precise compared to if we used a smaller sample size.

Then, half a cup of Cheerios was carefully measured, then poured into each of the sixty bowls. We randomly assigned treatments to the bowl of Cheerios, so we know the random condition will be met. Since we wanted equal sized treatment groups, we started by assigning a number between 1 and 60 to each bowl. Using a random number generator, we obtained a list of 30 unique numbers between 1-60. Those 30 numbers corresponded to the bowls of Cheerios that will sit in Lucerne 2% milk. The remaining 30 bowls were assigned to the Great Value 2% milk. One quarter cup of each brand of milk was carefully measured out and then placed into the bowls of cereal at fifteen second intervals. Each bowl was renumbered one through thirty for each milk brand (so there were two number one bowls, number one for Lucerne and number one for Great Value), and this way, we could record whether the Cheerios got soggy in each bowl by using the number in the data chart below that corresponded to each bowl. To avoid the confounding

variable of the cereal being submerged in milk for too long, we poured the milk into each bowl fifteen seconds after the previous to ensure that I could take a Cheerio out after exactly five minutes for each bowl. Also, we made sure that the same amount of pressure was applied to each Cheerio when I squished it using a glass cup. A glass cup was used to gently set on the Cheerio so that only its weight alone put pressure on the Cheerio, and if it flattened, then we determined it was soggy. If it held its shape, we determined that it was not soggy. This process was repeated for each of the sixty bowls, and if the Cheerio held its shape then I recorded "N," meaning not soggy, in the table. If the Cheerio did not hold its shape, then I recorded "Y," meaning it was soggy, in the table.

Data Display

Raw Data: *Lucerne* Milk Cereal Sogginess			
Bowl	Soggy? (Y/N)	Bowl	Soggy? (Y/N)
1	Y	16	Y
2	N	17	N
3	N	18	Y
4	N	19	Y
5	Y	20	N
6	Y	21	Y
7	Y	22	N
8	N	23	Y

Raw Data: *Great Value* Milk Cereal Sogginess			
Bowl	Soggy? (Y/N)	Bowl	Soggy? (Y/N)
1	Y	16	N
2	Y	17	N
3	N	18	N
4	Y	19	Y
5	N	20	N
6	Y	21	Y
7	N	22	Y
8	Y	23	N

9	Y	24	Y
10	N	25	N
11	Y	26	N
12	N	27	Y
13	Y	28	Y
14	N	29	Y
15	N	30	N

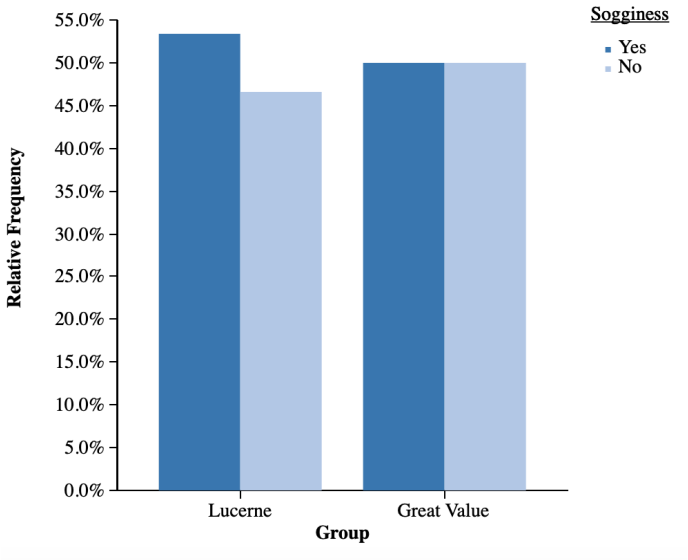
9	N	24	Y
10	N	25	Y
11	N	26	Y
12	N	27	N
13	Y	28	N
14	Y	29	Y
15	Y	30	N

Two Way Table: Frequency of Cereal Sogginess of Each Milk Brand

		Milk Brand		
		Lucerne	Great Value	Total
Sogginess	Yes	16	15	31
	No	14	15	29
	Total	30	30	60

Summary Statistics: Chi Square Test of Homogeneity for Cereal Sogginess in Milk Brands		
df = 1	$\chi 2 = 0.067$	p value = 0.796

Segmented Bar Chart of Relative Frequency of Cereal Sogginess in Milk Brands



The relative frequency of soggy Cheerios and not soggy Cheerios were very similar for both brands of milk. The Lucerne had a slightly higher frequency of soggy cereal at 53.3%. While the relative frequency of soggy Cheerios for the Great Value brand was 50%. The Lucerne milk had a higher relative frequency of soggy Cheerios (53.3%) than not soggy Cheerios (46.7%). The Great Value brand had the same relative frequency of soggy and not soggy Cheerios (50%). Thus, based on our segmented bar graph, it appears that the distribution of soggy Cheerios for Lucerne milk is different from the distribution of soggy Cheerios for Great Value milk with Lucerne milk having a slightly larger proportion of soggy Cheerios than Great Value milk. In order to determine if this difference is statistically significant, we would perform a chi square test of homogeneity if the conditions for performing this test were met.

IV. Data Analysis

The inference procedure used for this experiment would be a chi square test for homogeneity. This is the correct inference procedure in this case because we have 1 categorical variable with two independent populations. We can use this test if all conditions are met.

Conditions of Inference for Chi Square Test of Homogeneity:

1. **Random**: Bowls of cereal were randomly assigned each milk treatment using a random number generator in which each of the 60 bowls were assigned a number 1-60. We obtained 30 unique numbers between 1-60 to assign the bowls who corresponded to those selected numbers to Lucerne milk while the remaining bowls who corresponded to the leftover and not selected numbers received Great Value milk treatment.
2. **Normality:** We do not know if either the population distribution of soggy Cheerios in Lucerne milk or Great Value milk is normal. However, we can calculate the expected counts from our two way table in order to determine if the normality condition is met:

   Expected counts for Lucerne milk and soggy Cheerios $= \frac{(31)(30)}{60} = 15.5$

   Expected counts for Lucerne milk and not soggy Cheerios $= \frac{(29)(30)}{60} = 14.5$

   Expected counts for Great Value milk and soggy Cheerios $= \frac{(31)(30)}{60} = 15.5$

   Expected counts for Great Value milk and not soggy Cheerios $= \frac{(29)(30)}{60} = 14.5$

   All expected counts are greater than 5, so the normality condition is met.

All conditions were met, so we proceeded with calculations. Note, that we did not need to check the 10% condition since we included random assignment of treatments in our experiments and did not sample without replacement. Our treatment groups are independent because no bowl of Cheerios was subjected to sit in both brands of milk.

Calculations for Chi Square Test of Homogeneity:

$df = (n_{rows} - 1)(n_{columns} - 1)$ $df = (2 - 1)(2 - 1)$ $df = 1$	$\chi^2 = \sum \frac{(observed - expected)^2}{expected}$ $\chi^2 = \frac{(16-15.5)^2}{15.5} + \frac{(14-14.5)^2}{14.5} + \frac{(15-15.5)^2}{15.5} + \frac{(}{}$ $\chi^2 = 0.067$	$p\ value = 0.796$ $\alpha = 0.796$

Under the null assumption that there is not a significant difference in the distribution of Cheerios that get soggy in Lucerne 2% milk vs. Great Value 2% milk after sitting in milk for 5 minutes, the probability of observing a test statistic as extreme as this chi square test or more extreme is 0.796.

V. Conclusion

Because our p-value of 0.796, is greater than the significance level α= 0.05, so we fail to reject the null hypothesis. There is not convincing evidence that there is a difference in the distribution of Cheerios that get soggy in Lucerne 2% milk compared to Great Value 2% milk after sitting in milk for 5 minutes.

VI. Reflection

Based on this experiment we can infer that any bowl of Cheerios left in either Lucerne or Great Value milk after 5 minutes will have similar distributions of soggy Cheerios. Our inference is limited to the two brands of 2% milk we used and the one type of cereal we used, so we cannot make assumptions about any other brands, other types of milk (1% etc.), or other brands of

cereal since our experiment's scope of inference is not applicable for those scenarios. If we had used more brands of milk, types of milk, and more brands of cereal, our assumption may have been able to be more broad. There is the possible error in this experiment that the temperature of the brands of milks may have varied while we were pouring them into each bowl. This may have affected the distribution of soggy Cheerios of each milk brand since having slightly warmer milk may allow the Cheerios to absorb the milk more quickly, which would make the Cheerios soggy more quickly. Thus, there may have been an overrepresentation of soggy cereal in the distribution. Furthermore, how gently we placed the glass on the Cheerio likely varied between trials, which would affect deciding whether or not that bowl of Cheerios was soggy. With greater applied pressure than just the weight of the glass, the Cheerio would be flattened easier, leading to an overrepresentation of soggy Cheerios in the distribution. The distribution of sogginess may be the same in each type of milk because we may have let the Cheerios sit for too long or too short of an amount of time. Sitting in milk for too long, the distribution of the sogginess of Cheerios would be indistinct between the brands of milk since we do not know the average time it takes for Cheerios to get soggy in each milk brand. Thus, all of the cereal regardless of milk brand became soggy because it had an excessive amount of time to uniformly become soggy through diffusion. Sitting in milk for an insufficient amount of time, the distribution of the sogginess of Cheerios between milk brands may not have significant differences because not enough time was given for diffusion to occur in the cereal. We do not know the average time it takes for Cheerios to become soggy in each milk brand, and the 5 minutes that each bowl of Cheerios sat in milk may not have been enough for the Cheerios to start becoming soggy. Therefore, all of the cereal would still be crispy due to insufficient time and not the brand of milk. Perhaps, further experiments could be run in which each bowl was left at varying times,

such as 3 minutes or 10 minutes instead of 5, to determine if the distribution of soggy Cereal would be different than our experiment.

Overall, our project went smoothly, despite initial difficulties. When we first brainstormed ideas, we were cautious about choosing this topic since we were unsure how to measure the sogginess of Cheerios in a manner that would be consistent for all the bowls since squishing it between your fingers could vary between each trial. Ultimately, we decided that it would be best to rely on the constant weight of an inanimate object in order to reduce the variation in the power of people. With this statistical question, we knew we had to perform a chi square test of homogeneity if conditions were met, but we did not know if the normality condition would be met until we had experimental data because we couldn't have calculated the expected counts yet. Although it was tedious and a bit time consuming, we were able to have a sample size of 30 for each milk brand. In having a large sample size, we made our data more precise and reduced the variability between trials due to chance while also increasing the power of our test in correctly rejecting the null hypothesis when it is false. In regards to our theme of affordability, we did not find convincing evidence that Lucerne 2% milk, typically the more expensive milk, and Great Value 2% milk, typically the cheaper milk, differed in the distribution of soggy cereal. Therefore, in trying to decide between which 2% milk to accompany your Cheerios on a budget, Great Value milk would still keep your Cheerios as crispy at a lower cost.