STAT424 Group Project Written Report

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(1) Problem statement

Our experiment looks at the uncommonly known fact that putting raisins in a carbonated beverage will make them appear to dance in the beverage. This is due to the bubbles of carbonation getting caught in the wrinkles of the raisin as they rise to the surface of the container. As more bubbles get caught under the raisin, it becomes more buoyant and rises to the top. However, the uneven shape of a raisin causes its elevation to be uneven which allows for some bubbles to escape its wrinkles. The result is a raisin that moves sporadically in the beverage. Some refer to this as "Dancing Raisins."

In our experiment, we investigate various factors that can influence the release of carbon dioxide bubbles. We decided to use the time a raisin is suspended in the beverages as a way to measure this quantitatively.

(2) Choice of the factors and response

Our response variable is the amount of time between the raisin being dropped into a carbonated beverage and it falling to the bottom of the beverage. Our group considered many treatment factors including brand of beverage, type of carbonated beverage, temperature of the beverage, and the amount of raisins dropped into the beverage during the trial. It was determined that manipulating the temperature of the beverage and the type of carbonated beverage was the simplest design.

Temperature was set to have two levels: room temperature (21.89℃) and refrigerator temperature (4.83℃) as anything hotter or lower than these temperatures could cause our containers to explode. Type of carbonated beverage was set to have three levels where club soda, tonic water, and ginger ale are the different treatments. We wanted consistency in the beverage brand, volume of liquid, and size/shape of the bottle. These parameters were met by using Canada Dry's® 10 fl. oz. bottles of each type of beverage. Not only did this allow us to reduce the effects of confounding variables, but the translucent bottles and liquids were optimal for observing the raisins.

(3) Choice of the design

Our experiment will be conducted through Cross-Factor Design. This design is convenient given the limited resources and distance between the members of our group. The cross-factor experimental design requires fewer observations. In addition, this design is more likely to result in a significant effect provided that the effect is actually significant. In other words, the likelihood of a type II error is less when our treatment effect is significant.[1]

Normally, carry-over effects are a concern with cross-factor experiments but these effects are not an issue with this experiment as each trial uses a new bottle and a new raisin. Therefore, our observations are subjected to only one set of experimental conditions before and during this experiment.

Our experiment needed to be able to accommodate team members living in different parts of the world, so we decided to conduct an experiment using typical household items with a design that allows for any member to easily collect data while still being interesting. For this experiment, we had only one member of the team perform the experiment so that there would not

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[1] Stockburger, D. W. (1996). *Introductory Statistics: Concepts, Models, and Applications* [1.0]. Southwest Missouri State University

be inconsistencies in room temperature and fridge temperatures when collecting data. Our experiment had six different treatment combinations with three replications. In total, we had eighteen experimental units.

(4) Conducting randomization

To perform randomization, we listed each experimental combination and assigned a random number, one through eighteen inclusive, to each of the combinations. We then sorted our list by the randomly assigned number to obtain an order of application for our trials (shown in Figure 1). We labelled each of the bottle caps with their corresponding number and either placed them in the refrigerator or in the room where the experiment would be conducted. Then the labels were torn off of the bottles so that the beverage would be unknown to the experimenter and it provides easier viewing of the raisin. A picture of some of our labeled room temperature bottles are shown in Picture 1.

In addition, we randomly assigned each of our raisins to a corresponding treatment combination. This was done by assigning each of our raisins a random number one through eighteen and then using them with the matching application. This was to prevent potential biases when selecting which raisin from our eligible pool would be dropped into our beverages.

(5) Execution of the experiment

Initially, we wanted to eliminate as many potential confounding variables as possible before we started conducting our experiment. We made sure to exclusively use clear beverages from Canada Dry®, and so our treatment levels are tonic water, club soda, and ginger ale. Translucent beverages make observing the response much easier, and it is also important to note that the volume of each separate drink was strictly 10 fl oz. Each type of carbonated beverage had the same artificial carbonation process. This process is the most common in the industry. However, the ingredients of these beverages varied. All of our beverages shared carbonated water as an ingredient. Tonic water and ginger ale shared high fructose corn syrup, citric acid, sodium benzoate, and natural flavors as ingredients. The rest of the ingredients were exclusive to each drink. If these ingredients had an effect on our results, it would be indicated in our effects tests. Bottles subjected to more movement before the bottle is opened will have more turbulence in the liquid. This breaks the surface tension of the liquid which makes it easier for the bubbles to escape. We tried controlling this by allowing bottles to rest for 5 minutes before we opened them.

Inconsistency in raisin size and shape was initially a cause for concern, as we were weary of its effects on the amount of time in which a particular raisin dances. We operated under the assumption that smaller raisins with less surface area and raisins with larger mass would result in a decreased dancing time. Thus, we incorporated a food scale and a small tape measure into our experimental procedure and made sure to only utilize raisins that weighed out to about 0.5 grams and measured out to about 1.5 centimeters wide. However, our scale was only able to measure to the nearest tenth of a gram so there were limitations to our accuracy. In addition, the size and shape of each raisin is too random to accurately measure and account for given our resources. After we omitted every raisin that did not fit the given criteria, we took the usable raisins and wrapped them on a dry paper towel for about 12 hours before we proceeded placing them into the carbonated beverages. This was to ensure that the results of our experiment were not affected by differing levels of raisin moisture on the outer surface.

For each carbonated beverage, three bottles were placed in the refrigerator and the other three bottles were left to acclimate to room temperature overnight. The data was collected in a randomly assigned order shown in Figure 1. Before each trial, the temperature of the beverage was taken to ensure it had not significantly deviated from the desired temperature after the five minute resting period (Picture 2). As stated, each raisin was placed into its randomly assigned bottle (Picture 3). Using a stopwatch, we measured the time between the raisin entering the beverage and the raisin falling to the bottom of the bottle.

(6) Statistical analysis

From our ANOVA results (Figure 2 and Figure 3), we can state that while beverage type did not affect our response variable while temperature affected the response, because the p-value of beverage type effect is greater than our significance level of 0.05, while the p-value of the temperature effect is less than 0.05. Hence, we can reject the null hypothesis only for temperature, and conclude that only the temperature factor is statistically significant in its effect on raisin dance time and carbon dioxide release**.**

From the normal plot (Figure 4), we can conclude that our data is normally distributed and there is little deviation from normality in the data. Also we can verify it through the effect test (Figure 2), we observed that the F statistic with corresponding p-value is less than our significance level of 0.05, which showed that factor temperature is significant.

From the interaction plot (Figure 5), we would decide to say it's a mild relation, so we would choose “Case-I3”, Conduct the analysis using only the main effects. Interaction term is still in the model.

From a normal quantile plot (Figure 6), we observed that most of the points were closed to the line, which means that normality assumption is valid. Although there appears to be slight deviation from normality, these deviations are not significant and could be due to small sample size.

From the residual plots for temperature and soda type (Figure 7 and Figure 8) and the residual versus predicted plot (Figure 9), we observed that “Residual VS. Temperature” do not share the constant variance, so the assumption of analysis is not satisfied. However, “Residual VS. Type” shares the constant variance, the assumption of analysis is satisfied. Hence, there exists the effect of variability due to the temperature.

(7) Conclusion

Through the whole process of our experiment, we came to some useful conclusions. Firstly, the type of carbonated beverage has no effect on the dancing time of the raisins, which means that no matter which carbonated beverages we put a raisin in, the dancing time did not change significantly. In terms of temperature, differing levels of temperature indeed has a significant effect on the dancing time of the raisins, which means that as beverage temperature decreased, raisin dance time decreased as well.

Given the limited resources available to our group and the distance between each member, there is room for improvement in this experiment. It would be beneficial to the experiment if the shape of the raisin could be more effectively accounted for. In addition, a scale that can measure to the hundredth of a gram would more effectively eliminate mass of the raisin as a confounding variable. Furthermore, placing bottles from the refrigerator directly into an ice bath and letting them acclimate to the temperature of the ice bath may be a more effective way of controlling our low temperature. While we confirmed the temperature of the refrigerated beverage before running a trial, there might be some effect on our results as the cold liquid warms up to room temperature. An ice bath would have also allowed us to measure the effects of temperature at a larger difference between our levels.

Despite these weaknesses, our experiment was able to identify temperature as a significant factor in the release of carbonation and determined the type of carbonated beverage did not have a significant effect. Additionally, our experiment used temperatures that are most common for carbonated drinks to be consumed. This experiment diminished the effects of confounding variables as effectively as possible given the stated limitations.

(8) Contributions

Mark: Problem statement, choice of factors and variables, statistical analysis, and JMP code, conclusion, and edited presentation
Steven: wrote report and presentation, edited JMP code
Max K: collected data, wrote JMP code, edited report and presentation
Max N: Problem statement, choice of factors and variables, choice of design, randomization, created experimental procedure, conclusion and contributed to the corresponding slides on the presentation

(9) Figures and Plots

Figure 1

Randomly Assigned Number	Temperature Group	Beverage Group	Time
1	High	Club	164
2	Low	Ginger	190
3	High	Tonic	166
4	High	Ginger	38
5	Low	Club	46
6	Low	Ginger	213
7	Low	Tonic	21
8	High	Tonic	146
9	High	Ginger	43
10	Low	Ginger	232
11	Low	Club	43
12	High	Tonic	196
13	High	Club	220
14	High	Club	250
15	Low	Club	51
16	High	Ginger	26
17	Low	Tonic	25
18	Low	Tonic	30

This table shows the randomly assigned order of application for our data collection.

Figure 2

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Soda Type	2	2	0.129943	2.0902	0.1664
Temp	1	1	13.520991	434.9882	<.0001*
Soda Type*Temp	2	2	0.543195	8.7376	0.0046*

The ANOVA results for the treatment effects

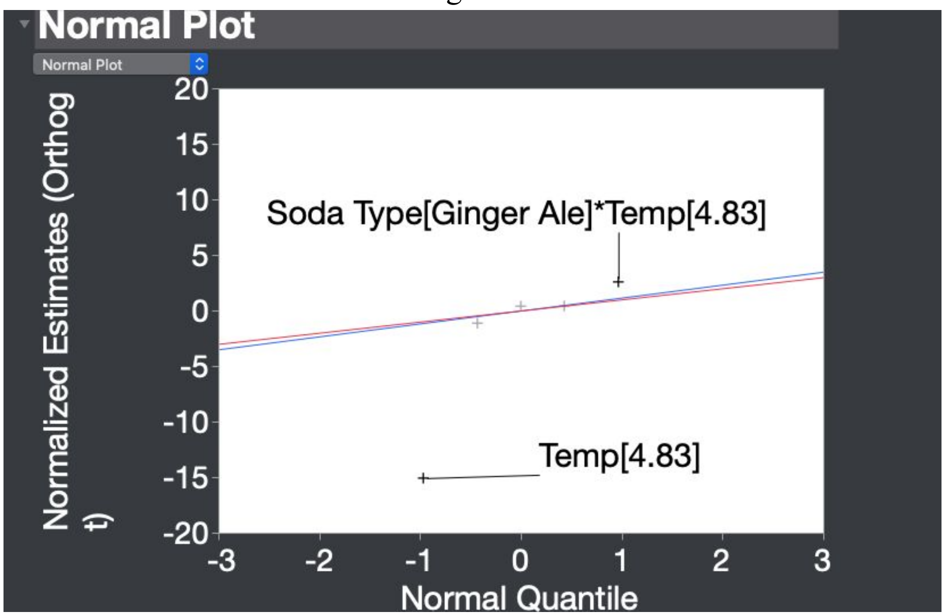
Figure 3

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	14.194129	2.83883	91.3288
Error	12	0.373003	0.03108	**Prob > F**
C. Total	17	14.567132		<.0001*

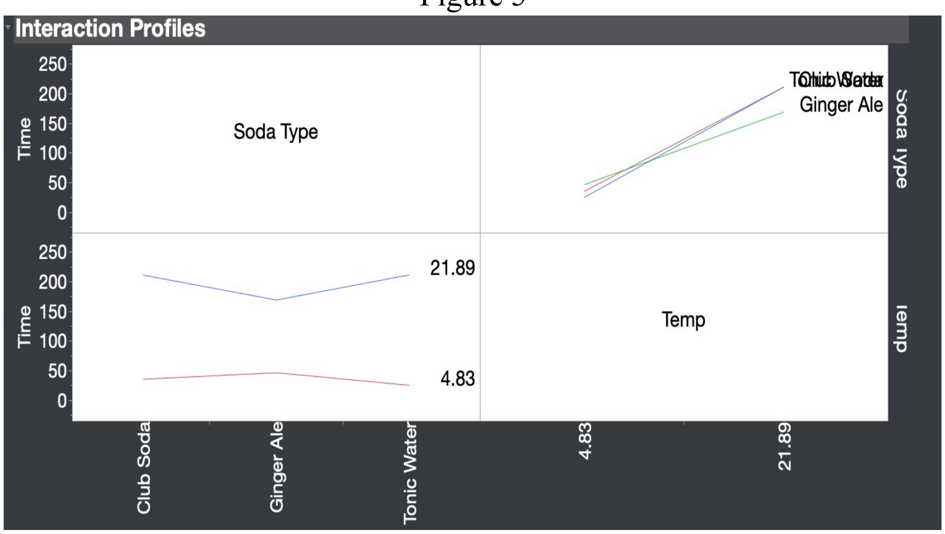
The ANOVA results for the overall model and error

Figure 4



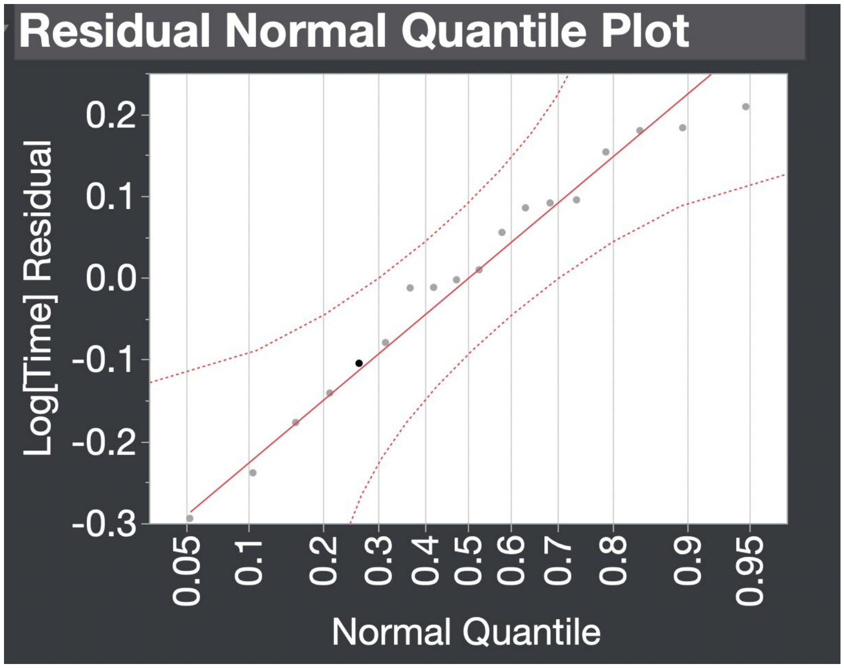
The normal plot generated using JMP

Figure 5



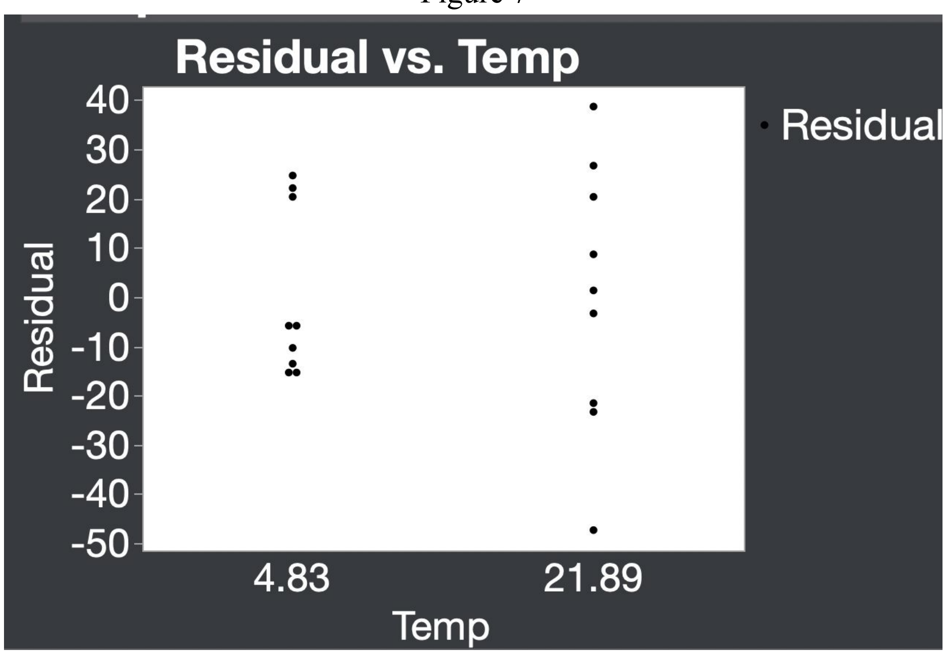
The interaction plots for the factors generated using JMP

Figure 6



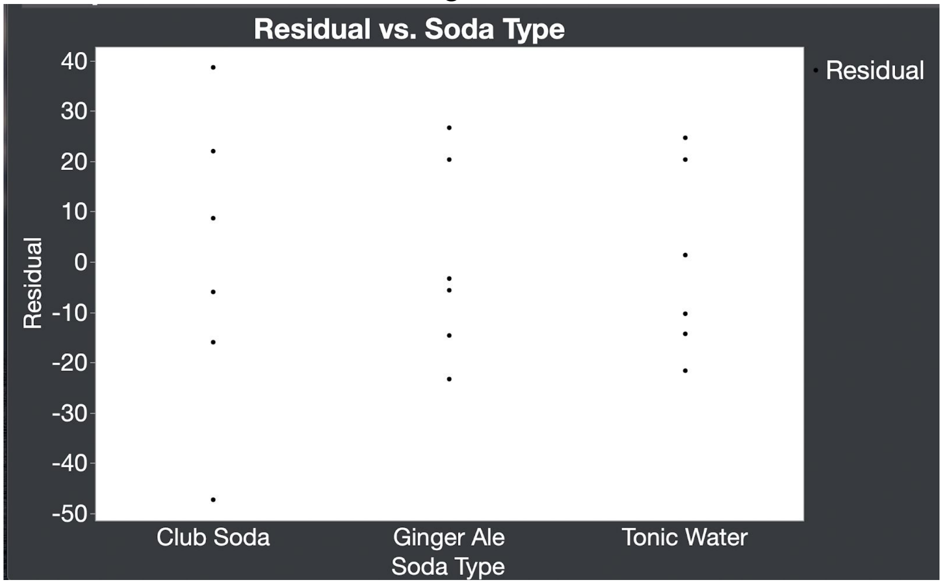
The normal quantile-quantile plot generated using JMP

Figure 7



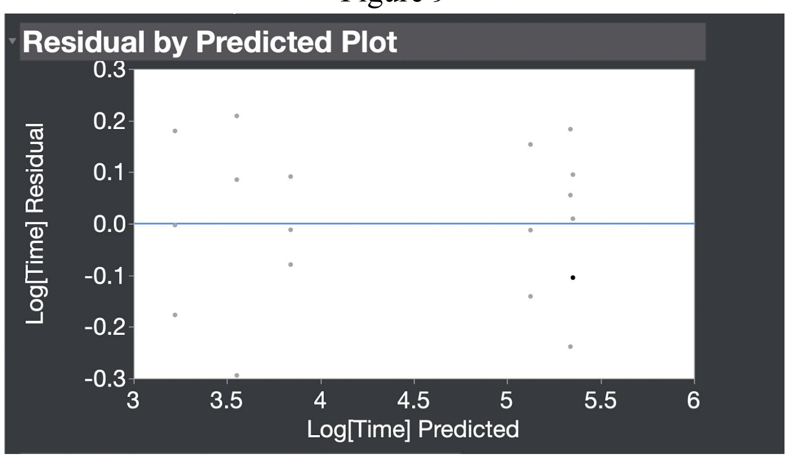
The residual plot for temperature generated using JMP

Figure 8



The residual plot for soda type generated using JMP

Figure 9



The residual by predicted plot generated using JMP

Figure 10

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.4048257	0.041556	106.00	<.0001*
Soda Type[Club Soda]	0.0404806	0.058768	0.69	0.5040
Soda Type[Ginger Ale]	0.077737	0.058768	1.32	0.2106
Temp[4.83]	-0.866698	0.041556	-20.86	<.0001*
Soda Type[Club Soda]*Temp[4.83]	-0.026314	0.058768	-0.45	0.6623
Soda Type[Ginger Ale]*Temp[4.83]	0.2246915	0.058768	3.82	0.0024*

Parameter estimates for the experimental model

Figure 11

Prediction Expression

$$
\begin{aligned}
&2.8514162333 \\
&+0.0979772467 \cdot \text{Soda Type} \\
&+0.1016059136 \cdot \text{Temp} \\
&+(\text{Soda Type}-2) \cdot ((\text{Temp}-13.36) \cdot -0.024798906)
\end{aligned}
$$

Prediction expression for the experimental model

Picture 1

Six of the nine bottles designated for room temperature treatment.

Picture 2

Checking the temperature of a fridge temperature beverage before conducting the trial.

Picture 3

A picture of a raisin being dropped into observation number 14.