# The Effect of Coffee Type and Temperature on pH

STAT 5204G Project Report

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## Motivation and Background

As all four of us are Coffeeholics and always wondered why we cannot experience from every coffee, same amount of refreshment. We were eager to find the reason behind it and went to our favorite coffee shop in downtown to do an experiment.

Now going little scientific about coffee, Acidity is a fundamental coffee flavor experience that can be described as a pleasant sharpness at the front of the mouth, a numbing feeling on the tip of the tongue, or a dryness at the rear of the palate and/or under the tongue's margins. It indicates or aids in the description of a coffee's quality. Acidity, along with body, fragrance, sweetness, bitterness, and aftertaste, is one of the key coffee qualities used by coffee specialists to characterize the flavor of a coffee.

The pH scale, which specifies how basic or acidic a water-based solution is, is commonly used to determine acidity. The scale runs from 0 to 14, with 0 being the lowest and 14 being the highest. Any solution with a pH of 0 to 7 is considered acidic, while those with a pH of 7 to 14 are considered basic.

In recent years many coffee drinkers are turning to "low-acid" coffees, usually due to a doctor's recommendation or a yucky feeling in their stomach after drinking their daily cup. Because of this trend in coffee drinkers of moving from high acidic coffees to a lower acidic coffee we decided to do an experiment on it. The experiment aims to determine the effect of different coffee beans on the pH level of the brewed coffee.

## Experimental Design

We have employed a Completely Randomized Block Design with 1 treatment factor and 1 blocking factor. The number of replications is 4.

Statistical Model:

$$y_{ij} = \mu + \tau_i + \beta_j + \epsilon_{ij} \; where\; i = 1 \; and\; j = 1$$

Here, $\tau_i$ is the effect of treatment i

$\beta_j$ is the effect of block j

$\epsilon_{ij}$ is the random error

Response Variable:
pH value of the coffee

Treatment Factors:
Coffee type - There will be four specific coffee types studied and will be considered random effects as they are four selected from the multitude of existing coffee types.

Blocking Factor and Levels:
Coffee temperature is considered to be the blocking factor and it has 2 levels, cold and hot.

Sample Size:
The size of sample to be tested for this experiment is 32 (8 of them for each coffee type and they are equally split between cold and hot)

## **Data Collection**

The data was collected utilizing the Vivosun pH meter.


4 different coffee types have been tested for both hot and cold temperatures. For each type of coffee 4 experimental units were used each for hot and cold. The coffee (experimental unit) to be tested has been freshly brewed each time the pH has been tested.


## Results and Discussion

The results of our experiment can be found in table 1 of the Appendix. Using these results we are able to conduct statistical inference on the effect of coffee type and temperature on pH.

To do so, we utilize the ‘General Linear Model’ within Minitab[3][4], which fits a model as specified in the Design of Experiments section. The results of this model are shown in Figure 1. The 2 hypothesis tests in consideration are the following:

$H_0$: $\sigma^2_{coffee}=0$
$H_1$: $\sigma^2_{coffee}\neq 0$

$H_0$: The average pH of all coffee temperatures is equal
$H_1$: The average pH all of all temperatures is not equal

We consider that the coffee types are random effects as they are a subset of the multitude of coffee types that exist, whereas the specifications of hot and cold are more universal.

## Analysis of Variance

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Roast | 3 | 0.42656 | 0.142186 | 169.14 | 0.000 |
| Temperature | 1 | 0.10013 | 0.100128 | 119.11 | 0.000 |
| Roast*Temperature | 3 | 0.02178 | 0.007261 | 8.64 | 0.000 |
| Error | 24 | 0.02017 | 0.000841 | | |
| Total | 31 | 0.56865 | | | |

Figure 1: Analysis of Variance Table

The results show that the interaction between the blocking factor, temperature, and roast is significant as the p-value<.05. Therefore we can conclude that there are differences in these levels, but to determine if there are differences between each of the factors pairwise comparisons must be conducted.

### Tukey Pairwise Comparisons: Roast

#### Grouping Information Using the Tukey Method and 95% Confidence

| Roast | N | Mean | Grouping |
|---|---|---|---|
| Decaf Sumatra | 8 | 4.80875 | A |
| Colombian dark | 8 | 4.74000 | B |
| Coconut cream | 8 | 4.61000 | C |
| House Blend | 8 | 4.51000 | D |

*Means that do not share a letter are significantly different.*

### Tukey Pairwise Comparisons: Temperature

#### Grouping Information Using the Tukey Method and 95% Confidence

| Temperature | N | Mean | Grouping |
|---|---|---|---|
| Cold | 16 | 4.72313 | A |
| Hot | 16 | 4.61125 | B |

*Means that do not share a letter are significantly different.*

Figure 2: Pairwise Comparison

The results of Tukeys pairwise comparison are shown in Figure 2. It is evident that both coffee roast and temperature are significant as each is separated into groups. The conclusion to draw from this is that both coffee type and temperature do have some effect on the pH, and subsequently on the qualitative features of the coffee as suggested in our motivating statement. From an intuitive perspective, different coffee's do have different tastes, and if pH is truly an underlying factor in taste, it is reasonable to assume different coffee's will have different pH values.

After conducting the analysis we verified that the assumptions of Analysis of Variance(ANOVA) are satisfied. Figure 3 contains the residual plots for the model and data utilized in this analysis. The normal probability plot does not provide great confidence in the normality assumption being satisfied. To further investigate we use the Anderson-Darling test, which is in figure 4 of the Appendix, has p-value of .06 which is greater than .05 therefore we can conclude that the normality assumption is satisfied. Constant variance does seem to be satisfied from the fitted value vs residual plot, but just to ensure it is we conduct the Levene test, in figure 5 of the appendix, which supports the conclusion of constant variance. The observation order vs residual plot does show that independence is satisfied. Therefore, all assumptions of ANOVA are satisfied.

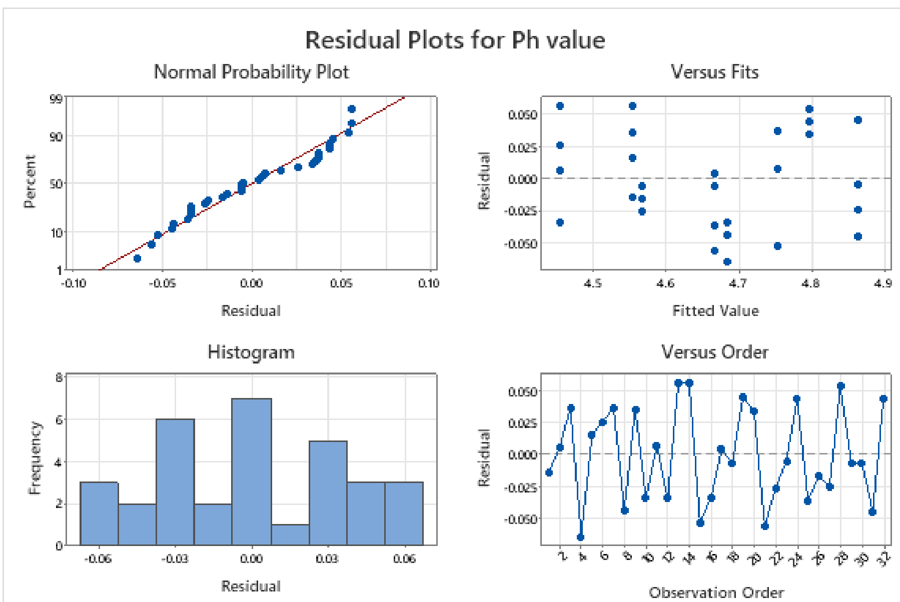


Figure 3: Residual Plots for ANOVA

## Conclusion

Before the experiment, we know that the strength of coffees from low to high is colombian dark, Decaf sumatra, Coconut cream and House blend. From the result of this experiment, it is clear that there is a significant difference between the pH values of the coffees as the strength of coffee beans changes. So, pH value can be treated as a measure to find the suitable strength of coffee for each person i.e., if a person finds a coffee at a certain pH perfect for them, they should find coffees that are in that pH level.

We also found a surprising result that pH value also changes with the temperature of the coffee. As the coffee is cooled down and pH value is measured, it gives a significant difference in the pH value. This implies that, Acidity of coffee, hence the strength of the coffee changes with the temperature of the coffee. So, if someone wants the coffee in the certain pH level but only has the certain blend or certain coffee beans available, then cooling down the coffee can help bring the coffee into the required pH level.

Overall experiment results are interesting and raises new questions that need to be explored. We wanted to make more experiments with the coffee using different design we learned in the course and want to find the ‘Perfect’ coffee for everyone.

## References

[1] Yeatts, Jennifer. “Coffee Acidity: The Science and the Experience.” *Higher Grounds Trading*, 17 Jan. 2019, https://www.highergroundstrading.com/blogs/news/coffee-acidity.
[2] Preiato, Daniel. “Is Coffee Acidic?” *Healthline*, Healthline Media, 6 Nov. 2019, https://www.healthline.com/nutrition/is-coffee-acidic.
[3] Minitab 17 Statistical Software (2010). [Computer software]. State College, PA: Minitab, Inc. (www.minitab.com)
[4] Quality Companion 3 by Minitab (2009). [Computer software]. State College, PA: Minitab, Inc. (www.minitab.com)

## Appendix

Table 1:

| Roast | Temperature | Ph value |
|---|---|---|
| Coconut cream | Hot | 4.54 |
| House Blend | Hot | 4.46 |
| Decaf Sumatra | Hot | 4.79 |
| Colombian dark | Hot | 4.62 |
| Coconut cream | Hot | 4.57 |
| House Blend | Hot | 4.48 |
| Decaf Sumatra | Hot | 4.79 |
| Colombian dark | Hot | 4.64 |
| Coconut cream | Hot | 4.59 |
| House Blend | Hot | 4.42 |
| Decaf Sumatra | Hot | 4.76 |
| Colombian dark | Hot | 4.65 |
| Coconut cream | Hot | 4.61 |
| House Blend | Hot | 4.51 |
| Decaf Sumatra | Hot | 4.7 |

| | | |
|---|---|---|
| Colombian dark | Hot | 4.65 |
| Coconut cream | Cold | 4.67 |
| House Blend | Cold | 4.56 |
| Decaf Sumatra | Cold | 4.91 |
| Colombian dark | Cold | 4.83 |
| Coconut cream | Cold | 4.61 |
| House Blend | Cold | 4.54 |
| Decaf Sumatra | Cold | 4.86 |
| Colombian dark | Cold | 4.84 |
| Coconut cream | Cold | 4.63 |
| House Blend | Cold | 4.55 |
| Decaf Sumatra | Cold | 4.84 |
| Colombian dark | Cold | 4.85 |
| Coconut cream | Cold | 4.66 |
| House Blend | Cold | 4.56 |
| Decaf Sumatra | Cold | 4.82 |
| Colombian dark | Cold | 4.84 |

Figure 4:

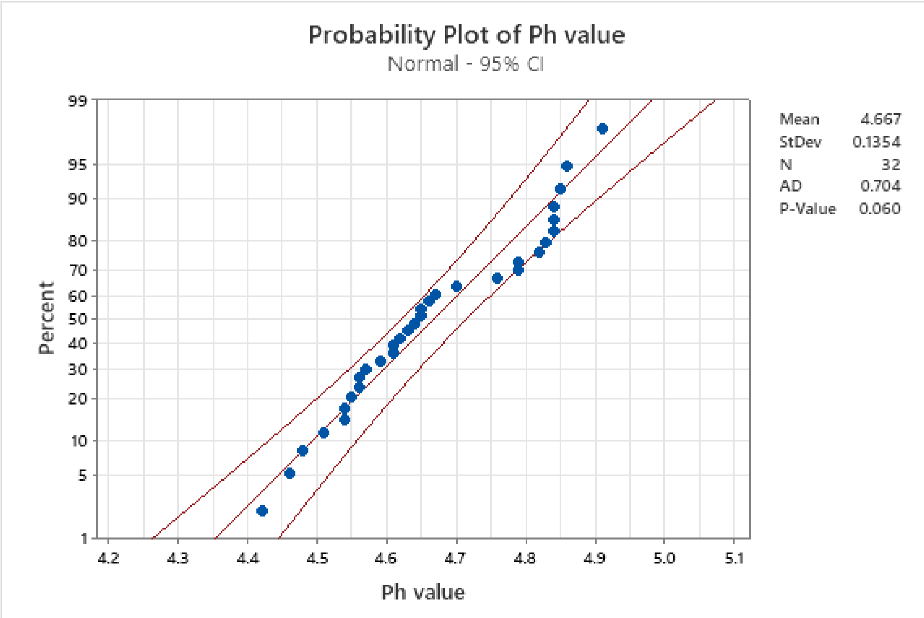


Figure 5: