The Concernment of Coffee: A Statistical Analysis of Coffee's Chemical Properties

Abstract

The purpose of this study was to determine the relationship between the flavor and the average pH of different brands of bagged coffee that can be purchased at Ralph's Supermarket in Orange, CA. Four randomly selected coffee bags were collected from each of the four randomly selected brands of coffee. The coffee bags were obtained through cluster sampling of the brands of coffee. The flavor variable was taken from the front label of each bag, while pH was measured by inserting a Vernier pH probe into ½ cup sample of coffee brewed from each selected bag. Using a one-way ANOVA test, a statistically significant difference between the average pH of at least two or more roasts/flavors was determined.

Background and Significance

According the National Coffee Association, a 2018 survey found that 64% of Americans drink at least once cup of coffee each day [1]. Most individuals consume coffee as means of in taking the secondary metabolite, caffeine. Caffeine is a central nervous system stimulant that antagonizes adenosine receptors, which causes an increase in locomotor activity within animals [2]. Aside from being a metabolic energy source, the consumption of caffeinated coffee is associated with a decreased risk for developing Alzheimer's Disease, according to a 2009 study [3]. Additionally, research conducted by Weinong et al. found that caffeine enhances the expression of pro-apoptotic genes in skin cells that have incomplete DNA repair, thus hindering the development of melanoma [4]. Based upon the significance and impact of consuming caffeinated coffee, we were curious to analyze some of the various commercial coffees' chemical properties, such as pH and its association with flavor. This criterion is of interest as consumers may discriminate against certain coffees qualitatively based upon its taste and perceived acidity.

This study aims to answer the research question, "Is there a statistically significant difference in the average pH of brewed coffee based on its flavor?". To answer this question, we performed the statistical test between the null hypothesis "*There is no statistically significant difference between the average pH of at least two or more of the coffee roasts/flavors*." (H_0: $\mu_{\text{pH Colombian}} = \mu_{\text{pH French Roast}} = \mu_{\text{pH Hazelnut}} = \mu_{\text{pH Italian Roast}} = \mu_{\text{pH Kona Blend}} = \mu_{\text{pH Vanilla}}$) and the alternative hypothesis that "*There is a statistically significant difference between the average pH of at least two or more of the coffee roasts/flavors*."

Methods

Coffee Selection

Sixteen bags of coffee were selected from Ralph's Supermarket in Orange, California using the cluster sampling method. The brands of the bagged coffee carried by Ralph's were used as sampling units for this study. There are seven name brands of coffee at Ralph's, namely Don Francisco's Dunkin' Donuts, McDonald's, Peet's Coffee, Private Selection, and Starbucks. Four (4) of these brands were randomly selected. Once the four brands were selected, a simple random sampling of the available bags of coffee within each brand was performed to obtain four (4) bags of coffee from each selected brand, resulting in a total sample of size 16 coffee bags.

pH Measurement Methods

The pH measurements were obtained by brewing ½ a cup of each sampled bag of coffee. Each sample of coffee was decanted into a 10-mL centrifuge tube and a Vernier pH probe integrated with a Logger Pro 2 apparatus that was calibrated with both a pH 4 and pH 7 buffering solution. This processed was repeated three times to obtain three true replicate measurements. The average of the pH from each coffee sample across the three trials were calculated to summarize the results.

Data Analysis

All raw data collected in this study was recorded in Google Sheets. The raw data was then converted into a text file and input into R Studio. R Studio was used to compute the average pH and the standard error measure of the pH data. Additionally, R Studio was used to conduct an ANOVA test on the pH differences between the flavored coffees, as well as Tukey's Honesty Significant Difference Test (HSD) Test. Moreover, all graphics in the figures below were generated using R Studio. Throughout the study, the level of significance ($\boldsymbol{\alpha}$) was equated to 0.10.

Results

The results of this study show that the hazelnut flavored coffee has the lowest average pH of 5.26 with a standard error measure (SEM) 0.042, while the French Roast has the highest average pH of 6.12 with an SEM of 0.16. Figure 1 below represents this information graphically. In order to answer our research question, we ran an ANOVA test. The computed p-value was found to be 7.57E-7, which indicates that there is a statistically significant difference between the average pH of at least two or more of the coffee roasts/flavors. To determine the pairs of coffee roasts/flavors that have significantly different average pH's, we ran a Tukey's HSD Test. The statistically significant results are presented in Table 1.

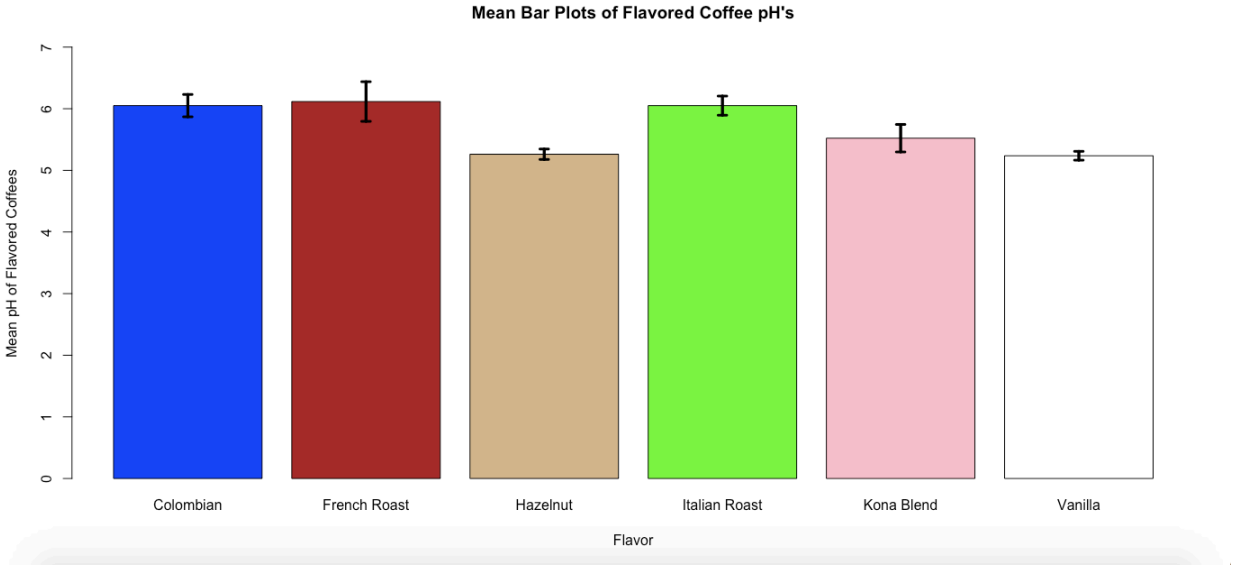

Figure 1. The bar plot above represents the distribution between the mean pH by flavor of all flavored coffees selected.

Table 1. Statistically Significant Results of Tukey's HSD Test on Average pH of Coffee Flavors/Roasts

Coffee Flavors	Adjusted p-value
Hazelnut-Colombian	0.0010107
Kona Blend-Colombian	0.0415237
Vanilla-Colombian	0.0006969
Hazelnut-French Roast	0.0000223
Kona Blend-French Roast	0.0024438
Vanilla-French Roast	0.0000143
Italian Roast-Hazelnut	0.0010107
Kona Blend-Italian Roast	0.0415237
Vanilla-Italian Roast	0.0006969

Conclusion

Based on the results of the ANOVA test and the Tukey's HSD Test, we found that there is a statistically significant difference in the average pH of coffee across different flavors. With respect to the chemistry of these results, as observable in Figure 1, hazelnut flavored coffees exhibit mild acidity as the mean pH of this flavor is significantly lower than Colombian, French, and Italian Roast Coffees. This is due to the presence of phytic acid within hazelnuts, which is a mildly acidic chemical [5]. Similar to hazelnuts, Kona coffee beans contain more chlorogenic acid than many coffee beans [6]. The Kona Blend coffee is particularly more acidic than the Colombian, French, and Italian Roast flavors. Regarding the vanilla-flavored coffees, the presence of the mild vanillic acid causes this flavor of coffee to be relatively acidic [7]. Specifically, the vanilla flavored coffees studied are significantly more acidic than Colombian, French, and Italian Roasts.

These results may suggest that consumers are willing to tolerate coffee acidity in flavored coffees, especially granted that a majority of the coffee bags selected were flavored/distinct from an "original" or "classic" roast.

With respect to limitations in this study, the samples were collected by convenience from one local grocery store. In order to obtain more diverse data with respect to the flavors and brands of coffee, selecting coffees from other stores would provide a more accurate representation of the coffee brand population. Moreover, only three pH measurements for each sample were recorded. Increasing the amount of pH measurements would generate results that are inherently more accurate. Last, the tap water source used to brew each coffee may have influenced the pH of the coffee; this variable was not taken into consideration and was assumed to be pH neutral (pH 7).

References

[1] Sherman, E. Americans Are Drinking More Coffee Than Ever. https://www.foodandwine.com/news/americans-drinking-more-coffee-ever (accessed Dec 12, 2018).

[2] Nehlig, A.; Daval, J. L.; Debry, G. Caffeine and the central nervous system: mechanisms of action, biochemical, metabolic and psychostimulant effects. https://www.ncbi.nlm.nih.gov/pubmed/1356551 (accessed Dec 8, 2018).

[3] Eskelinen M.H., Ngandu T., Tuomilehto J., Soininen H., Kivipelto M. Midlife coffee and tea drinking and the risk of late-life dementia: a population-based CAIDE study. J. Alzheimers Dis. 2009;16(1):85–91. doi: 10.3233/JAD-2009-0920.

[4] Weinong H, Ming M, and He Y. (2011, May 11). Caffeine Promotes Ultraviolet B-induced Apoptosis in Human Keratinocytes without Complete DNA Repair. *Journal of Biological Chemistry* (2011), 286(26): 22825–22832.

[5] "The Acid Alkaline Food Guide"; Dr. Susan E. Brown, et al., 2006.

[6] Hawaiian Kona Blend. https://www.coffeebeandirect.com/hawaiian-kona-blend.html (accessed Dec 12, 2018).

[7] Vanillic acid. https://pubchem.ncbi.nlm.nih.gov/compound/vanillicacid (accessed Dec 12, 2018).