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A Bayesian Correlational Study on Three Coffee Bean Type and Brewing

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Abstract

Barako Coffee is a coffee variety unique to the Philippines, and the research gaps showed an absence in the study of Barako Coffee and immersion brew time. Other bean types (Arabica and Robusta) were included due to the rarity of Barako Beans, as they are only sourced from a specific farm in Batangas and Cavite. This study hopes to contribute to the literature using a single experiment Bayesian correlation between brew time and perceived bitterness. The single experiment is done over three months, yielding 100 cups of coffee using three types of coffee beans: Arabica, Robusta, and Barako. For each brew, the variables of bean type, perceived bitterness, dilution of coffee, and brew time duration in minutes were correlated. Correlation analysis was done using Bayesian Analysis (BF10) in favor of the alternative hypothesis, which states a significant correlation exists between these Variables. Statistical Correlation pointed out that only two variables have a significant correlation. The first set of variables is Bean Type and Bitterness, which has a strong positive correlation, with a Pearson rho of 0.670 and BF10 Value of $3.366\times10^{+1.}$ The second variable is minutes of brew time and dilution, with a Pearson rho of 0.355 and a BF10 of 80.519; a strong evidence of correlation. These two variables were significant at the alpha level of 0.05. The findings validated the commercial application of longer brew time to yield a more robust cup of coffee; however, they also raised the need for further investigation and study on the variables of Brew Time and Dilution. AeroPress Coffee is known for the dilution of coffee brew. Perhaps dilution can also be used to adjust the taste of coffee to personal preference. This research article is a product of the research capability training conducted by the University of the Visayas during the summer of 2024, which focuses on applying Bayesian correlation using Jeffrey's Amazing Statistical Program.

Keywords: *Barako, correlation, brew time, manual coffee brewing*

Introduction

The Research Gap. The gap of this study is based on the search results using the keywords "Barako, correlation in Google Scholar that showed a measly 216 research articles published regarding the said coffee varietal. Most of the published articles focused either on the agricultural process or the business side of coffee making (Barlan, 2013; Frajenal, 2022), but only a handful of articles discuss the brewing process of the Barako coffee beans. Coffee is a complex drink that relies on how the coffee beans are harvested, processed, roasted, and brewed. Even making a simple coffee latte involves physics, as proven by Xue et al. (2017). These points to the fickle nature of making a good cup, compounded further by our tongues' different taste sensitivity (Val, n.d.). How the human tongue can perceived tasted was explained as "The human receptors convert the chemical response to electronic nerve impulses whose unique patterns are propagated by neurons (Patel & Doddamani, 2019, p. 17); what they were able to develop can only imitate but can never produce the same sensitivity of the human tongue. It is a popular belief that Barako is not known even popular within its origin, as stated by Isleta et al "In Lipa City, where Kapeng Barako originated and is famous for. Only a few coffee shops use the Kapeng Barako beans on their products or base of their products even if the beans are known in the city (p.118, 2023)".

The Statement of purpose. The primary intention of this article is to explore the application of Philippine coffee beans (Arabica, Barako & Robusta) when brewed via AeroPress Coffee maker. In pursuit of such a goal, the following sub-problems have been developed.

1. Descriptive statistics determine the mean value of the perceived bitterness and duration of brew time in minutes.
2. Describe the types of coffee beans used.
3. Describe the various brewing tools used.
4. Perform Bayesian correlation on perceived bitterness, brew time, dilution and bean type variables.

The Null Hypothesis

H_{01} There is no significant relationship between Bean type and perceived bitterness.
H_{02} There is no significant relationship between Bean type and duration of brewing (Minutes).
H_{03} There is no significant relationship between Bean type and coffee diluting.
H_{04} There is no significant relationship between perceived bitterness and duration of brewing (Minutes).
H_{05} There is no significant relationship between perceived bitterness and diluting (or not) of the coffee.
H_{06} There is no significant relationship between the duration of brewing (Minutes) and diluting the coffee.

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The opposite of the statements above is the alternative hypothesis.

The Variables of the Study. Barako Coffee, locally means stud, is a heritage food. It accounts for 2% of the entire coffee world production, and its taste is well-loved by Filipinos despite its earthy, herbal-like taste profile (Hue, n.d.). It is a coffee unique only to the Philippines. This particular bean was selected as it represents the basic Filipino in the coffee industry. Brew time is a variable used in immersion brewing. It was proved by Ludwig et al. (2012) that modern technology can speed up brew time and improve coffee extraction to make tastes bolder and more robust. Due to the rarity of sourcing purely Barako beans, other bean types and brewing methods were also included. The inclusion aims to emulate the daily use of various brewers.

Brewing Materials used: AeroPress Coffee maker, Hario V60 brewer, and French press.

Review on related literature. Angeloni et al. (2019) proved that the Cold Brew method of brewing produces a high coffee extraction of as much as 450mg/ml caffeine. This literature is important as it shows the impact of longer immersion periods of 12-72hrs of coffee immersion. Angeloni and the company also used AeroPress and other brew methods like espresso machine, moka pot, and French Press. It must be stated that this is an American study. In the Philippines, local. Studies focused on the agricultural impact of coffee production (Habaradas & Mia,2021), while other local studies focus on the technical chemical aspect of coffee production. Alvindia & de Guzman (2021) is a prime example of exploring the presence of fungi in selected coffee farms in Northern Luzon, Abra, Cavite, and Davao; found out that disinfecting coffee plants (Arabica, Liberica aka Barako, Excelsea, Robusta) with a low 1% dosage of disinfection may help to diminish the impact of fungi while penicillin use saw a reduction of infection by 20%. No local study was found to have focused on the application of Barako coffee bean in brewing.

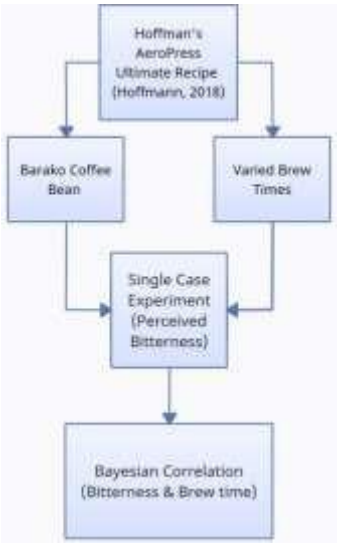

Figure 1 – *Theoretical Framework*

This study uses the Ultimate AeroPress Recipe (Hoffmann, 2018) as the primary coffee brewing recipe, only altered by the brewing time and tasting experiments. The subjective nature of tasting can also impact on the quality of the experiment since there is no standard to determine taste preference (Spotten et al., 2017).

Methodology

Research Method. A single experiment was undertaken where 100 coffee cups were brewed over a three-month period using 11-18 grams of arabica/Barako with an output of 60-80ml often diluted to 250ml, providing a 1:10-14 ratio of coffee extraction. The Barako Coffee Bean was used with a coarse grind, while the Brew time between the cups was spaced by 1 minute, 3 Minute , 5 Minute, 10 Minute intervals. Various brewing instruments were also employed to factor in the varied use of different brewers. Data collection and recording is immediately done while taste-testing is to be done 5 minutes after brewing to make brewed coffee at room temperature. Perceived Bitterness was rated on a scale of one to four while brew time and coffee brewed output was measured. Room temperature was essential to the taste since findings of Yeager et al. (2022) showed that coffee at room temperature allows for ease of identifying specific coffee notes and tastes.

Instruments used and sourcing of beans. AeroPress, one scoop of coarse grind to medium-fine ground coffee beans, approximately 11-14grsm. The Barako and Robusta beans were roasted by Gulf Coast Coffee Roasters stall at Escario Street Cebu City. In contrast, the Arabica bean was a premium Colombia Nariño Arabica Coffee bean imported and

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roasted by The Good Cup Coffee Co. Ramos Street Cebu City. AeroPress Go coffee maker, a smaller version of the standard AeroPress with a brew Capacity of 200ml, is the main coffee brewing instrument with a natural paper filter used to minimize coffee grit and particles. **Statistical analysis**. Bayesian correlation with a Bayes factor of 10 in favor of the alternative hypothesis is used for correlation, as this allows for the opinion to be a factor in the analysis where a hypothesis or alternate hypothesis is favored.

In 2017, Nuzzo pointed out, "Unlike P values, simple Bayesian analyses can provide a direct measure of the strength of evidence both for and against a study hypothesis, which can be helpful for researchers for interpreting and making decisions about their results" (p.1278). Descriptive statistics is also used. The primary statistical software for Bayesian analysis is Jeffrey's Amazing Statistical Program (JASP), an open-source statistical program that anyone with a restriction on licensing fees can use. JASP is a robust statistical software that also provides data visualization, with the data tabulation being sourced and made public, allowing for verification of the results. Understanding Bayes Factor 10. Unlike the traditional regression method the null hypothesis, Bayesian Statistics allows the testing of both null and alternative hypotheses in one synchronized method, choosing Factor 10 in favor of the alternative hypothesis or Factor 01 in favor of the null hypothesis (Schreiner & Kunde, 2024). As explained in Statistics How to (n.d.) "When we are comparing two hypotheses, H1 (the alternate hypothesis) and H0 (the null hypothesis), the Bayes Factor is often written as B10. It can be defined mathematically as:

$$\frac{\text{likelihood of data given } H_1}{\text{likelihood of data given } H_0} = \frac{P(D|H_1)}{P(D|H_0)}$$

Interpreting BF10. Table 1 below shows how Bayesian Factor 10 is interpreted. At the same time, the p- value of the Pearson rho is used to provide strength in the relationship between the variables.

Table 1
BF10 Factor Interpretation Guide (Nuzzo, 2017, p.1280)

Bayes Factor BF_{10}	Label
>100	Extreme evidence for H_1
30—100	Very strong evidence for H_1
10—30	Strong evidence for H_1
3—10	Moderate evidence for H_1
1—3	Anecdotal evidence for H_1
1	No evidence
1/3—1	Anecdotal evidence for H_0
1/10—1/3	Moderate evidence for H_0
1/30—1/10	Strong evidence for H_0
1/100—1/30	Very strong evidence for H_0
< 1/100	Extreme evidence for H_0

BF — Bayes factor.

Limitations of the study. The temperature was straight off the boil with no measurement to emulate how ordinary people would use coffee. The grind type used was coarse over all the coffee beans to mute the perceived bitterness of the brew. Total Dissolved Solutions and coffee extraction percentage was not measured to simplify the study. Data tabulation is also available online for verification and repeatability.

Data Tabulation availability
https://github.com/AljorizEdD/CoffeeData/blob/main/Coffee_v2.csv

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Results

Figure 2
Pie chart of Coffee Beans used

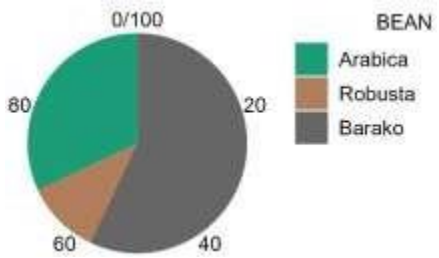

Figure two shows the distribution of the beans used in this study, 60% Barako beans were used while 10% Robusta and 20% Arabica beans were used, mixing of beans was performed to account for the identification of distinct levels of bitterness and preservation coffee flavor by Bean type.

Table 2
Distribution plot of coffee dosage by gram used

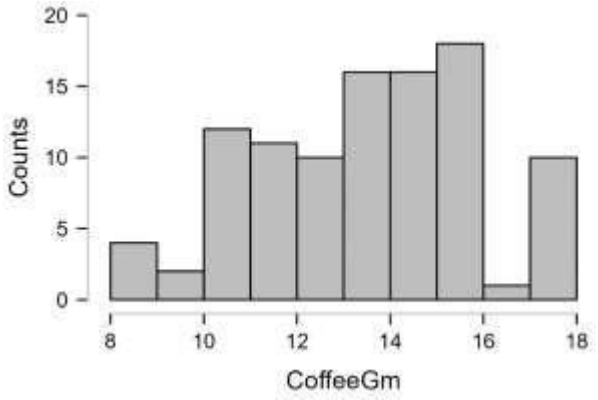

Table 2 shows the range of coffee grams used in the study, ranging from 8-18 grams, since the coffee brewed is for personal consumption. The Golden Ratio of 1:20 of the Specialty Coffee Association of America is believed to be more suitable for larger commercial brewing, Prince (2024) proposed a tighter coffee ration of 1:7 or one tablespoon for single drink brewing however in reality human's that we are consistency is not a strong suit there are days we use less or more than the desired coffee ratio.

Table 3
Descriptive Statistics of the variables

	Minutes	Bitterness	Dilute	Coffee In	Coffee Out
Mean	2.730	3.020	1.540	13.906	103.100
Std. Deviation	1.601	0.816	0.846	2.434	61.288
Minimum	1.000	2.000	0.000	8.000	30.000
Maximum	5.000	4.000	2.000	18.000	270.000

Mean, Standard Deviation, Minimum, and Maximum were used for the descriptive statistics. For the Brew time, the mean was around 2.73 minutes. Each cup has a standard deviation of 2 minutes, the lowest is less than 1, and the highest is five minutes. The brew time varies since the inventor of Aeropress, Alan Adler, wanted to minimize the brew time as he believes it produces the bitter taste of coffee (Szuster et al., 2020). A maximum of 5-minute brew time was observed in French Press, while 2-3 minutes of draw time was observed for Hario V60 coffee dripper. The bitterness was rated on a Likert scale, and the Dilute was coded a 1 for dilution and zero for non-dilution. The column Coffee in refers to the coffee grounds in grams. In contrast, Coffee out refers to the liquid brewed coffee in milliliters.

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Table 4
Distribution Plot by Method

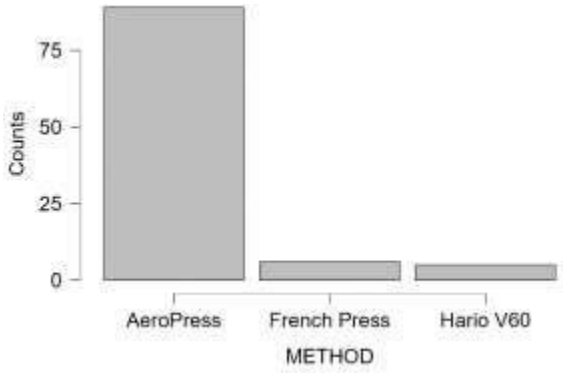
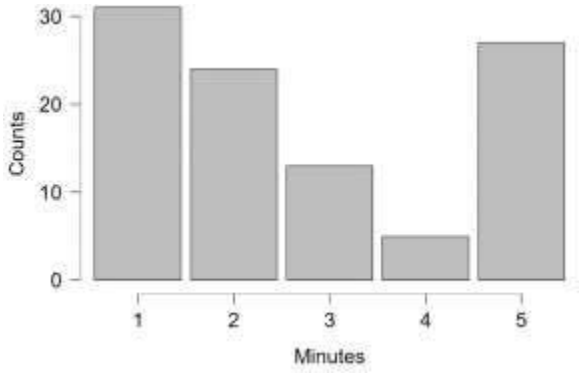


Table 4 shows the distribution plot by method where AeroPress takes a huge chunk of the brewing process.

Table 5
Distribution plot by Brew Time (Minutes)



The table above shows the distribution of brewing coffee by minute. The French Press takes an entire five minutes of brewing process. In contrast, Hario V60 as a filter coffee, takes between 2-4 minutes depending on the grind size and pour strength, while AeroPress has a range of one to two minutes of brew time.

Image 1.0
Arabica vs Barako and coffee puck fine grind vs coarse

The image above shows the coffee bean used, a specialty coffee bean from The Good Cup Coffee Co of Cebu, was observed to have an even roast profile, producing a wine and fruity finish to the coffee cup, while Barako Coffee beans were observed to be uneven in the roasting process producing pungent and earth like cup. The image on the right shows the visual difference between coffee pucks from AeroPress between fine and coarse grind sizes.

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Image 2.0
The AeroPress Brewing chamber

The left image above shows the medium-fine grind of arabica coffee beans, the white parts are the coffee chaff. Barako on the other had does not have a coffee chaff, the chaff is the outer layer inside the coffee bean that may add bitter flavors. The image on the right shows the slurry of the coffee

Brew just before adding pressure for coffee extraction, and a chocolate-like finish is observable in an Arabica Bean.

Correlations

Table 6
Bayesian Pearson Correlations

		Pearson's r	BF_{10}
BEAN	- Bitterness	0.670***	$3.366\times10^{+11}$
BEAN	- Minutes	0.067	0.155
BEAN	- Dilute	0.046	0.138
Bitterness	- Minutes	0.027	0.130
Bitterness	- Dilute	-0.191	0.750
Minutes	- Dilute	0.355**	80.519

* BF_{10} > 10, ** BF_{10} > 30, *** BF_{10} > 100

The correlation Matrix finds correlation only between the paired variables of Bean-Bitterness with a Pearson Rho of 0.670, Minutes of Brew Time and the ability to dilute has a Rho of 0.355 with a BF10 of 80.519 interpreted as "very strong evidence" for the alternative hypothesis. The variable Minutes and Dilute has a Rho of 0.355 and a BF10 of 80 interpreted as "moderate evidence of correlation". Other variables were not found to be significant.

Figure 3
Prior and Posterior for Bean and Bitterness

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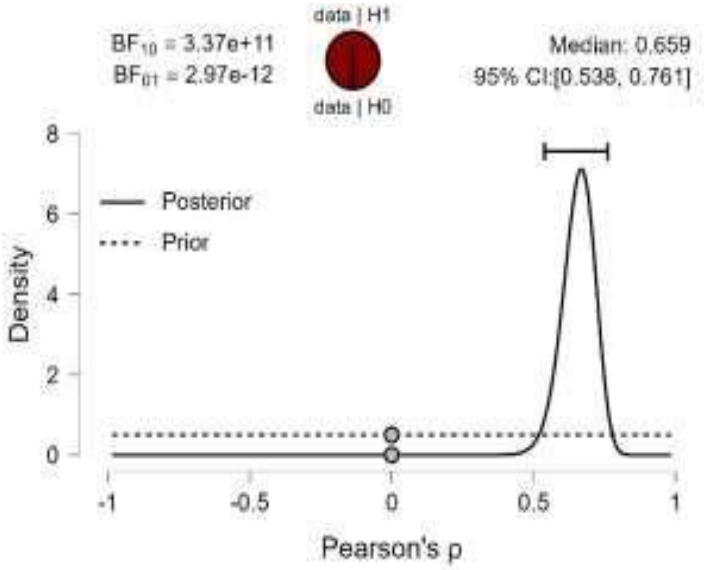

Figure 3 is the data analytical presentation of the correlation between the Bean variable and the bitterness variable. The Posterior has a Median of 0.659 the BF10 value of 3.37e+11. Given the strong Bayes Factor in favor of H1, there is substantial evidence that there is a non-zero correlation between the variables. The positive median value suggests a moderate positive correlation.

Figure 4
Prior and Posterior for dilute and minute variables

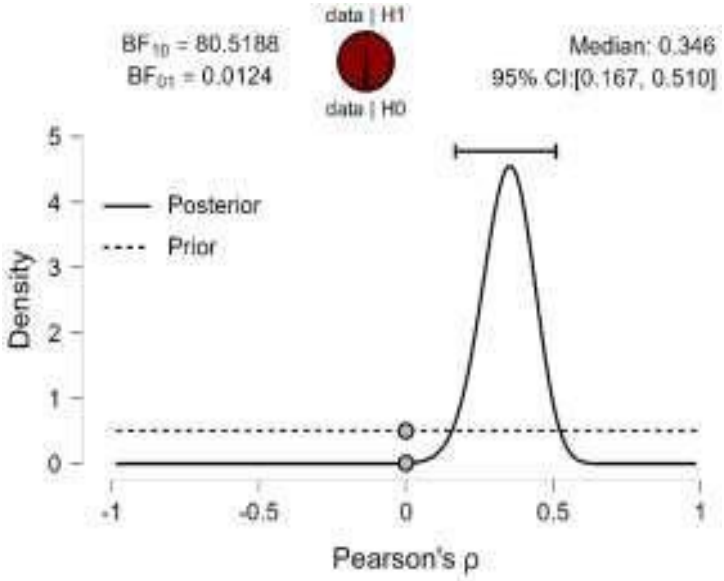

Figure 4 shows the prior and posterior distribution for the variable dilute and minutes of brewing. The solid curve (posterior distribution) is bell-shaped and centered around 0.3. The dashed curve (prior distribution) represents initial beliefs before data analysis. The Bayes Factors (BF_{10} and BF_{01}): BF_{10} (Bayes Factor for H1 over H0) is approximately 80.5188, indicating strong evidence in favor of hypothesis H1. BF_{01} (Bayes Factor for H0 over H1) is approximately 0.0124, suggesting weak evidence for H0. The median value of Pearson's ρ is 0.346. the Pearson value indicates moderate correlation. The implication of the table shows strong favor to support the alternative hypothesis.

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Table 7
Summary of Bayesian Correlations

VARIABLES	Rho (Pearson)	BF10	INTERPRETATION	DECISION
Bean Type and Bitterness	0.670***	3.366×10+11	Strong positive	Significant
Bean Type and Minutes	0.067	0.155	Very weak positive	Not Significant
Bean Type and Dilute	0.046	0.138	Very weak positive	Not Significant
Bitterness and Minutes	0.027	0.13	Very weak positive	Not Significant
Bitterness and Dilute	-0.191	0.75	Weak Negative	Not Significant
Minutes and Dilute	0.355**	80.519	Very Strong	Significant

* BF_{10} > 10, ** BF_{10} > 30, *** BF_{10} > 100

Implications of the correlations. The Bean type and bitterness strong correlation specially when the earthy, muddy flavors of Barako beans are considered, this has application to commercial such correlation is not new since Córdoba, et al. (2021) proved that brew time couples with high brew time affects extraction rate, thus a longer brew time would result to bitterness in the coffee thus necessitating adding milk or sweetener. Strong positive correlations on Bean Type and Bitterness suggest that Bean type has a direct impact on the bitterness of coffee despite various brew methods, the significant correlation points to a direct relationship. Minutes and Dilute was found to have a moderate positive correlation and significant, this means that the number of minutes of brew time is an element to determine whether to dilute the brewed coffee or not. While statistically significant, the effect maybe minute in statistical importance hence there is a need for further investigation on these variables. Diluting coffee brew is a common factor in the recipe made by Alan Adler, the inventor however recent recipes in "Aeromatic app" (available for Android and iOS) and the updated recipe by AeroPress calls for the absence of dilution. The findings also point to the possibility of using dilution to lower the strength of the coffee.

Conclusions. Barako coffee can benefit from shorter brew time and bypass (adding hot water) to make the brewed cup more palatable, but the degree of bitterness is still present as per Lim (2020). Coffee types were found to have a direct impact on the perceived bitterness of coffee thus buyers should consider the roast-type and grind type of beans to be used. Home brewers are encouraged to do cupping tests and continually to brew their own cup.

Recommendations. Coffee buyers must consider the roast type, coffee bean type and grind type when brewing coffee. Brew Methods are not much of a factor in the bitterness. For commercial coffee making, Barako beans can be used despite its pungent taste. For home brewers, it is recommended to know their personal coffee preference in buying coffee beans to match their unique preference. Due to the nature of single case experiments, duplicating this study is recommended to undergraduate students. Marketing through transparency can be considered as a factor for the success of any coffee shop (Thabit & Raewf, 2018).

Limitation of the Study. The following factors were not considered and recorded in the study for simplicity: Water Temperature, Total Dissolved Solids present in the water used. Water off the boil was used for the experiment. All beans were purchased and sourced only within the Philippines.

In summary, there is correlation between the variables of Bean type and Bitterness, Duration of brew time in minutes against the decision to dilute or not, thus adding water to the brewed coffee.

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