Project Report: Optimization of Hot Brew Coffee Quality

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Executive Summary

The purpose of this project was to optimize the taste of making hot brew coffee. By looking at three specific factors. They are weight of coffee, grind size, and water temperature. We aimed to determine how each affects the taste of coffee. Our experiment systematically varied these factors to identify their individual impacts on coffee taste quality. Our findings showed that both the weight of coffee and the grind size significantly impact the taste, while the water temperature does not. Specifically, using 1 tsp size coffee and a medium grind size led to better-tasting coffee. These results provide a clear direction for enhancing coffee quality by focusing on the quantity of coffee used and the fineness of its grind. This research offers valuable insights for both home brewers and professional baristas, guiding them towards the most effective brewing practices to achieve optimal coffee flavor.

We started this project because coffee is a staple in many people's daily routines. Achieving the perfect cup of coffee can be challenging because there are so many variables that influence the final taste. Factors such as the type of coffee beans, the type of coffee makers, the grind size, the amount of coffee used, the brewing time, and the water temperature all play crucial roles. Each of these elements must be carefully controlled and balanced to create the desired flavor, and even small variations can lead to significantly different results. This complexity makes it difficult to consistently brew a perfect cup of coffee, whether you're a home enthusiast or a professional barista.

In this study, we carefully selected three factors that baristas and coffee brewing guides frequently highlight as crucial to coffee flavor. These factors are the weight of the coffee, the grind size, and the water temperature. By focusing on these key elements, we aimed to identify the optimal conditions that produce the best-tasting coffee.

We conducted a full factorial experiment, testing each factor at two levels, resulting in eight unique combinations of the factors. Each combination was replicated three times to ensure the reliability of our results, leading to a total of 24 experimental runs. This thorough approach allowed us to evaluate both the main effects of each factor and their interactions.

Our statistical analysis revealed that the weight of the coffee and the grind size had significant effects on the taste quality of the coffee. Specifically, a lighter weight of coffee and a medium grind size were found to produce the best-tasting coffee. In contrast, water temperature did not have a significant effect within the range tested (180°F and 200°F). These findings suggest that coffee lovers should focus more on adjusting the coffee weight and grind size to achieve a better taste.

By using an organized approach and carefully studying the data, we were able to bridge the gap between theory and practice in coffee brewing. This study provides clear and actionable insights that can help coffee lovers and baristas refine their brewing techniques for consistently better results.

In conclusion, this research offers practical recommendations for optimizing coffee brewing, emphasizing the importance of coffee weight and grind size. These findings can help improve the daily coffee experience for many people, making it easier to enjoy a perfect cup for a long time.

Introduction

Coffee is one of the most beloved beverages, especially in the United States, but the secret to brewing a perfect cup remains a widely discussed topic. The nuances of brewing methods, the type of beans, and the brewing equipment can all influence the final taste of the coffee. This project aimed to understand how different brewing factors affect the taste of hot brew coffee by testing them systematically. With more people wanting to make the perfect cup of coffee at home and in cafes, this study used a structured approach to find the best brewing methods to improve coffee taste. By systematically changing the weight of coffee, grind size, and water temperature, we were looking to uncover the specific conditions that yield the best-tasting coffee. This approach not only helps in understanding the science behind coffee brewing but also provides practical recommendations for coffee enthusiasts. This study provides a clear and organized approach to coffee brewing, offering detailed results that help connect the scientific theory with real-world practice. It aims to help both coffee lovers at home and professional baristas improve their brewing methods to make the best possible cup of coffee. By following the guidelines and findings from this research, anyone can refine their techniques and achieve consistently better-tasting coffee.

Selection of the Response Variables

The main goal of this research was to improve the taste of hot brew coffee by testing different brewing factors. We focused on three main factors: the weight of the coffee used, the size of the coffee grind, and the temperature of the water poured. These factors were chosen because they are often mentioned in coffee brewing guides and by baristas as important elements that can change the taste of coffee. The response variable for this study was the taste quality of the coffee, rated on a scale from 1 to 5 by a specific coworker. The ratings were based on flavor, aroma, and overall satisfaction.

Choice of Factors, Levels, and Ranges

To thoroughly investigate how different brewing parameters influence the taste quality of hot brew coffee, we employed a full factorial design. This approach allowed us to explore the effects of three key factors, each tested at two distinct levels. The three factors chosen were weight of (A) coffee, (B) grind size, and (C) water temperature.

By using a full factorial design, we were able to evaluate not only the main effects of each factor but also their interactions. This design allowed us to systematically test every possible combination of factors and levels, resulting in eight unique combinations.

This comprehensive approach ensured that we could thoroughly investigate how each factor and their interactions affected the taste quality of the hot brew coffee. By understanding these relationships, we aimed to identify the optimal brewing conditions that would produce the best-tasting coffee.

Choice of Experimental Design

We conducted a full factorial experiment to further investigate how coffee weight, grind size, and water temperature affect the flavor quality of hot coffee. Each of these three factors was tested at two different levels: coffee weight at 1 and 2 tablespoons, coarse and medium grind size, and water temperature at 180°F and 200°F. This configuration resulted in eight unique combinations of these factors.

To ensure the reliability of our results, we decided to replicate each combination two times. This replication not only helps in averaging out any variability in the responses but also provides a better estimate of the experimental error. Consequently, the experiment consisted of a total of 24 runs (8 combinations $\times$ 3).

For this experiment, we used Peet's "Dark Roast Whole Bean Coffee" from Costco, a ceramic pour-over coffee maker that we purchased from Amazon, a gooseneck kettle and a manual grinder so the level of grinding can be controlled. These tools were selected to ensure a high level of consistency and control over the brewing process, and the coffee beans were kept into a contain with airtight seal technology, so it will slow down the process of oxidizing of coffee beans.

The experiment involved preparing one or two cups of coffee each day according to a randomized factors combination of coffee of the experimental conditions. This randomization was to avoid any biases that might be caused from brewing order, timing or skills (brewing or grinding). Over time, the quality of coffee beans may degrade even though I only grind coffee beans before brewing. Each cup of coffee was given to the same designated coworker (a long-time coffee lover) every time, who rated the taste on a scale from 1 to 5.

I limited myself to brewing only one or two cups per day to minimize the impact of changes in my brewing that might affect the coffee taste. Drinking too many cups in a single day could lead to a change of taste by the taster, which might skew the results. By spreading the experiment over several days and keeping the number of cups per day low, I aimed to maintain a high level of consistency in the brewing process.

This entire procedure was repeated until all randomized combinations had been tested three times. By following this systematic process, we made sure that each combination of factors had an equal chance of being tested on any given day. This approach helped minimize the influence of external variables on the results.
Once the taste ratings were collected from the coworker, they were directly inputted into the JMP statistical software for detailed analysis.

Statistical Analysis of the Results

To analyze the data, we used both graphical and analytical methods. The Actual by Predicted Plot generated by JMP provided a visual representation of how well our model performed. This plot showed that the data points aligned closely with the predicted outcomes, indicating a good fit for our model. By comparing the actual taste quality ratings to the predicted values, we were able to confirm that our model quite accurately captured the relationship between the brewing factors and the coffee's taste quality. This showed that our model was effective in explaining how the different brewing factors affected the taste quality.

The Residual by Predicted Plot further validated our model by showing that the differences between the actual and predicted ratings were spread out randomly around zero. This random spread means that our model's predictions were fair and unbiased. Additionally, the Studentized Residuals plot showed that most points were within the +/-2 range, indicating that there were no major errors or issues with our model. This plot helped us ensure that our model was reliable, and the data did not contain any significant outliers that could distort the results.

The Effect Summary provided a detailed look at the significance of each factor and their interactions. The weight of coffee and grind size showed significant effects on the taste quality (P-values of 0.0008 and 0.0117). This means that changes in these factors had a significant impact on the taste of the coffee. On the other hand, the water temperature did not show a significant effect (P-value = 0.1334), suggesting that within the tested range, it did not play a major role in influencing the taste.

The Prediction Profiler was a valuable tool for visually representing these effects. It showed negative and positive slopes for the weight of coffee and grind size, indicating their impact on taste quality. Specifically, using less coffee (lower weight) improved the taste quality, so a medium grind size enhanced the flavor. This visual representation made it easier to understand the overall taste.

The Cube Plot provided a three-dimensional representation of how the factors interact with each other. From this plot, we can see that the combination of a medium grind size (B = 1) and 1 tablespoon of coffee (A = -1) consistently produced high ratings, regardless of the water temperature (C). This visualization further supports our findings.

Additionally, the Interaction Profiles helped visualize how different combinations of factors affected taste quality. These plots did not show significant interactions, meaning that the effects of the factors were independent of each other. For instance, the impact of the coffee weight on taste quality did not depend on the grind size or water temperature, and vice versa. This independence simplifies the optimization process because we can adjust each factor separately without worrying about complex interactions.

In summary, the statistical analysis confirmed that our model was accurate and reliable. The key findings highlighted the importance of coffee weight and grind size in determining the taste quality of hot brew coffee, while water temperature was less critical within the tested range. These insights provide a clear direction for optimizing coffee brewing methods to achieve the best possible taste.

Conclusions and Recommendations

The results from the analysis showed that increasing the weight of coffee tends to decrease the taste quality, The medium grind size seems performed better than coarse. These findings are particularly useful for individuals and businesses to enhance their coffee brewing practices.
Also, the lack of significance in water temperature and the interactions suggests that these factors are less critical than the amount and grind of the coffee. This insight simplifies the brewing process, indicating that if the temperature is within a reasonable range, it may not need to be precisely controlled. Given these results, if further experiments were conducted, they should focus on refining the levels of coffee weight and grind size beyond the ranges initially tested here. Additionally, exploring other factors, such as brewing time or different types of coffee beans, could provide further insights into achieving the best taste coffee.
This project not only clarified which factors are most important to brew high-quality coffee but also showed the application of experimental design.
For future work, expanding the experiment to include more variables, more nuanced levels within the significant factors could continue to build on the foundation this project has laid. Moreover, involving multiple tasters could help to generalize the findings.
In conclusion, this research has successfully identified key factors that affect the taste quality of hot brew coffee and provided a clear path for further research and practical application.

References

Rushing, Heath, Andrew Karl, and James Wisnowski. 2013. *Design and Analysis of Experiments by Douglas Montgomery: A Supplement for Using JMP*. Cary, NC: SAS Institute Inc. ISBN 978-1-61290-725-3.

Montgomery, Douglas C. 2020. *Design and Analysis of Experiments*. 10th edition. Hoboken, NJ: Wiley. ISBN 978-1119492443 (ePub), ISBN 978-1119492498 (pbk.), ISBN 978-1119492474 (ePDF).

JMP Data and Plots

Factors and Levels:

Weight of Coffee (Factor A)

-1: 1 tablespoon
1: 2 tablespoons

Grind Size (Factor B)

-1: Coarse grind
1: Medium grind

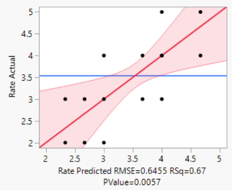
Water Temperature (Factor C)

-1: 180°F
1: 200°F

	Pattern	A	B	C	Rate	Predicted Rate
11	+−−	1	-1	-1	3	2.6666666...
12	−−+	-1	-1	1	4	4
13	+++	1	1	1	5	4
14	−−−	-1	-1	-1	4	3.6666666...
15	+−+	1	-1	1	2	2.3333333...
16	−+−	-1	1	-1	4	4
17	+−+	1	-1	1	2	2.3333333...
18	+−−	1	-1	-1	3	2.6666666...
19	+−+	1	-1	1	3	2.3333333...
20	−++	-1	1	1	4	4.6666666...
21	+++	1	1	1	3	4
22	−+−	-1	1	-1	4	4
23	−−−	-1	-1	-1	3	3.6666666...
24	−−−	-1	-1	-1	4	3.6666666...

Response Rate

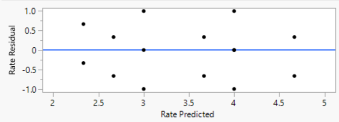
Actual by Predicted Plot



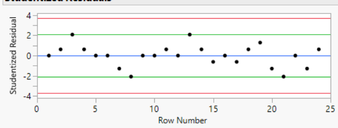
Effect Summary

Source	Logworth	PValue	
A	3.087	0.00082	
B	1.933	0.01168	
C	0.875	0.13341	
B*C	0.875	0.13341	
A*B*C	0.447	0.35689	
A*B	0.447	0.35689	^
A*C	0.122	0.75592	^

Residual by Predicted Plot



Studentized Residuals



Externally studentized residuals with 95% simultaneous limits (Bonferroni) in red, individual limits in green.

Summary of Fit

RSquare	0.665971
RSquare Adj	0.519833
Root Mean Square Error	0.645497
Mean of Response	3.541667
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	7	13.291667	1.89881	4.5571
Error	16	6.666667	0.41667	Prob > F
C. Total	23	19.958333		0.0057*

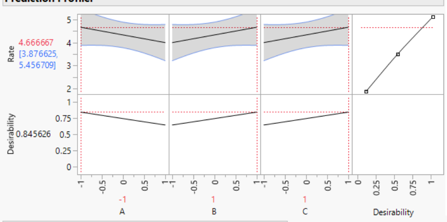
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.5416667	0.131762	26.88	<.0001*
A	-0.541667	0.131762	-4.11	0.0008*
B	0.375	0.131762	2.85	0.0117*
C	0.2083333	0.131762	1.58	0.1334
A*B	0.125	0.131762	0.95	0.3569
A*C	-0.041667	0.131762	-0.32	0.7559
B*C	0.2083333	0.131762	1.58	0.1334
A*B*C	0.125	0.131762	0.95	0.3569

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
A	1	1	7.0416667	16.9000	0.0008*
B	1	1	3.3750000	8.1000	0.0117*
C	1	1	1.0416667	2.5000	0.1334
A*B	1	1	0.3750000	0.9000	0.3569
A*C	1	1	0.0416667	0.1000	0.7559
B*C	1	1	1.0416667	2.5000	0.1334
A*B*C	1	1	0.3750000	0.9000	0.3569

Prediction Profiler

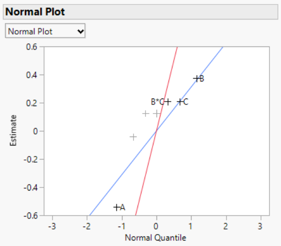


Effect Screening

The parameter estimates have equal variances.
The parameter estimates are not correlated.

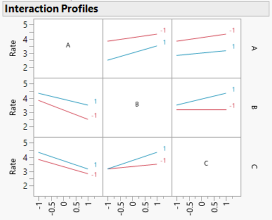
Lenth PSE
0.3125

Normal Plot



Blue line has slope equal to Lenth's PSE.
Red line has slope 1.

Interaction Profiles



Cube Plot