To Oil or Not to Oil: An Investigation into Agrabathi and Old Wive's Tales

STA2005S

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Abstract

A quatitative analysis of the burn time of Agrabathi when covered in various common oils found in Indian households.

Table of contents

1 Introduction

Incense sticks, or Agrabathi, have been a part of cultural and spiritual practices for centuries, especially in the Indian subcontinent. These fragrant sticks are commonly used in religious rituals, meditation, and household ceremonies, where their slow, steady burn releases aromatic smoke that permeates the air. The burning of incense is more than just a sensory experience—it holds deep cultural significance, symbolizing the connection between the physical and the spiritual realms.

However, despite the widespread use of incense sticks, little scientific research has been done to investigate factors that might influence their burn time. There is an abundance of varying anecdotal theories which all claim to alter the burn rate of Agrabathi, but these claim remains largely unexamined. This assignment will explore one such claim: the influence of different oils on the burn rate of Agrabathi.

2 Motivation

For generations, families across the Indian subcontinent have followed a long-held belief that applying oil to incense sticks, known as Agrabathi, causes them to burn faster. This old-wives tale, passed down through the ages, was believed to ensure that the sacred smoke swiftly filled the home with fragrance, creating an atmosphere for prayer and meditation. The faster burning time, in particular, was thought to facilitate a stronger connection with the divine, symbolizing the quick ascent of prayers to the heavens.

While the cultural and spiritual significance of incense sticks is undeniable in Indian homes, there remains a question: does applying oil to incense sticks truly accelerate burn time? This study seeks to investigate the validity of this age-old belief, providing modern families with data to determine whether applying oils such as castor and coconut oil is a meaningful practice or simply a tradition without scientific support.

By scientifically evaluating the effects of applying oils to incense sticks, this study aims to empower families to make informed choices about their usage of oils - potentially saving costs on unnecessary oils if they are found to have no significant effect. This experiment not only seeks to reveal the truth behind the belief but also strives to contribute practical knowledge to everyday practices that have long been part of cultural rituals.

3 Objectives

The study's objective is to determine which treatment has an effect on burn time looking at three treatments: a control, castor oil, and coconut oil. It will examine whether these commonly used oils differ from each other (comparison of castor and coconut oil) and whether there is a difference between the oils and the control (comparing the oils to the control). By acknowledging the differences that might arise due to manufacturing or material quality, blocking for brands serves as a crucial step in isolating the true effects of the oil treatments. By structuring the experiment in this way, the study aims to minimize the impact of confounding variables, allowing for the attribution of any variations in burn time more confidently to the treatments themselves rather than to the intrinsic characteristics of the incense sticks. Once the incense sticks are lit and the smoke clears, the last Agrabathi stick will reveal whether oils truly influence burn time.

Formally this study will test the following hypothesis:

> ℹ H_0: The application of different oils has no effect on the burn time of Agrabathi
> H_A: The application of at least one of the oils has an effect on the burn time of Agrabathi

Additionally the following two comparisons of means will be conducted:

> ℹ L_1: Effect of castor oil is equal to the effect of coconut oil.
> L_2: The effect of no oil is equal to the average effect of applying the oils

4 Design and Procedure

This experiment will employ a randomised block design with a single treatment factor - application of oil - of three levels, viz., control (no oil), coconut oil, and castor oil. The experiment will block for heterogeneity of experimental units arising from the use of different brands of Agrabathi viz., Hem, Malarani and Tulasi.

The factor levels have been selected as they are oils commonly used in Indian households across the world and are the de facto choices during day to day use. The brands of Agrabathi from which the experimental units are drawn from represent easily found and widely exported brands.

By acknowledging the differences that might arise due to manufacturing or material quality, blocking for brands serves as a crucial step in isolating the true effects of the oil treatments. By structuring the experiment in this way, the study aims to minimize the impact of confounding variables, allowing for the attribution of any variations in burn time more confidently to the treatments themselves rather than to the intrinsic characteristics of the incense sticks.

A pilot study will be conducted to assess the viability of the experimental procedure which is outlined below:

1. Select experimental units from each brand of Agrabathi
2. Randomly assign treatments to the units within each block
3. Apply the relevant treatment in the form of coating the sticks of Agrabathi in the appropriate oil ensuring that there is even and consistent covering
4. Light the Agrabathi sticks at their tip and place them in a sheltered area to burn
5. Record the time taken of the Agrabathi to completely burn

Precise details about the randomisation procedure will be discussed in Section 5

To reduce variance in the experiment due to external factors several steps will be taken to ensure that the experimental conditions will be kept consistent:

1. The Agrabathi will be burnt in the same area to prevent confounding due to location
2. The Agrabathi will be sheltered from wind and sunlight to prevent confounding due to increased airflow over the flaming tip and increased energy due to the sunlight
3. The blocks will be burnt at 10 minute intervals from each other to reduce confounding due to time. The interval is given to allow for the experimenters to set up and light the Agrabathi. This also allows for the majority of the Agrabathi in each group to burn concurrently to further reduce confounding due to time as well as increase the efficiency of the experiment.

The response variable is the time taken for the Agrabathi to burn given in seconds. The measurement of this was achieved via online stopwatch websites and the data was then manually transcribed.

5 Randomisation

Randomisation took place within each block of 3 experimental units (EUs). The procedure was as follows:

1. Label the EUs 1-3
2. Generate three random numbers between 1 and 1000 and iteratively assign them to the EUs (first generated number to EU 1, etc.)
3. Sort the random numbers in ascending order
4. Assign the treatments to the EUs using this ordered list, i.e., the EU corresponding to the lowest random number will be assigned the control treatment of no oil, the second number will get the coconut oil treatment and the largest number will get the castor oil treatment
5. Repeat 1-4 for all three blocks
6. Repeat 1-5 for every replication of the experiment

A sample randomisation for a singly replicated experiment is given in Table 1.

Where A,B, and C correspond to the treatment of no oil, coconut oil and castor oil respectively. The full randomisation used is given in the Appendix.

Table 1: Sample Randomisation

	1	2	3
Hem	B	A	C
Malarani	C	A	B
Tulasi	C	B	A

6 Pilot study

The pilot study was run with 18 experimental units and blocks were replicated twice.

Several difficulties were experienced while conducting the pilot study. Due to the large volume of smoke produced by the Agrabathi as it burnt, the experiment had to be conducted outdoors. This made it difficult to control for environmental factors such as wind, humidity, and sunlight. Additionally it was difficult to determine exactly when the Agrabathi stopped burning and thus there are slight non-systematic errors in the measurements of the burn times due to experimental error.

The original data is provided in the appendix. A basic descriptive analysis was conducted to analyse the data:

Table 2: Basic descriptive statistics

	Median	Mean	SD
Control	2243.44	1951.10	549.10
Coconut Oil	2780.95	2642.46	390.76
Castor Oil	2835.09	2712.11	321.78

The grand mean is 2435.23 and grand sample standard deviation is 537.57. From Table 1, one notes some differences in the means across the three treatments. The control group shows the lowest mean burn time but displays the highest standard deviation out of all the treatments. This may be due to the heterogeneity of experimental units. The oil treatments show smaller standard deviations which may be indicative of a treatment effect. Additionally all three treatments display a positive skew. These insights suggest a need for more data to test for significant effects.

7 Data Collection and Generation

The full experiment will consist of 30 replications per block using the same experimental and randomisation procedure as outlined above. The data was simulated based on the preliminary estimates for group means and sample standard deviations which were obtained from the pilot study. In total 90 observations were simulated.

The full simulated data is given in the appendix.

8 Model

This study will employ the following model for the data:

$$Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$$

Where $\varepsilon \sim N(0, \sigma^2)$ is the error term, $1 \leq i \leq 3$ indexes the treatments, $1 \leq j \leq 3$ indexes the blocks. Additionally we employ the sum to zero constraint such that $\sum_{i=1}^{3} \alpha_i = \sum_{j=1}^{3} \beta_j = \sum_{ij} (\alpha\beta)_{ij} = 0$. Additionally we assume an interactive model and thus include the possibility of interaction between block and treatment effects.

Each of these terms are interpreted as follows:

1. μ is the overall mean
2. α_i is the main effect of the i-th level of the treatment factor (oil application)

3. β_j is the main effect of of the j-th level of the blocking factor (brand)
4. $(\alpha\beta)_{ij}$ is the interaction between the i-th level of the treatment and the j-th level of the blocking factor.

This model will make the following assumptions:

1. Homoscedasticity
2. Normally distributed error terms
3. Independent observations

These assumptions will be justified and assessed during the model checking stage of the paper.

9 Outline of Analysis

The analysis of results will aim to provide conclusive evidence to support or reject the a priori hypothesis of this study as well as evaluate the root causes of these results my means of analysing the contrasts of interest. The study then goes on to check the validity of the model used and justify the assumptions which underlay the model and its subsequent analysis.

10 Effect Analysis

The effects of each treatment were computed using the sum-to-zero constraint specified in the model. The interpretation of these values follows those outlines in Section 8.

Table 3: Table of effects

Treatment	Effect	Block	Effect
Hem	-412.73	No oil	371.6
Malarani	166.67	Coconut oil	155.39
Tulasi	246.07	Castor oil	-526.99
Standard Error	106.84	Standard Error	107.78

The effects of the treatments indicate how each oil influences the burn time of the incense sticks relative to the average burn time:

1. 'No oil' results in a shorter burn time by 412.7 seconds compared to the baseline, suggesting that oil treatments extend the burn duration.
2. 'Coconut oil' increases the burn time by 166.7 seconds, indicating a moderate effect compared to the baseline.
3. 'Castor oil' has the largest effect, increasing the burn time by 246.1 seconds, making it the most effective treatment for extending the burn time.

This suggests that both oils increase the burn time of the incense sticks, with 'castor oil' being the most effective. The negative effect of 'No oil" reinforces that the oils play a role in slowing the burn rate.

The standard error for the treatment effect is 106.84 seconds, which gives us an idea of the precision of the estimated treatment effects. A smaller standard error would indicate more precise estimates, but in this case, the standard suggests some level of uncertainty in the treatment effect estimates.

The block effects show how the different brands inherently have differing burn times. This speaks to the heterogenity of the brands with 'Tulasi' having the shortest burn time and 'Hem' having the longest burn time on average.

The standard error for blocks is 107.78 seconds, indicating that the variability within the blocks or experimental units is relatively low. This reflects that the blocking (by brand) helped reduce some variability in the experiment. This suggests that the treatment effects are unlikely to be due to random variation alone, however this will be more closely analysed by the ANOVA.

In summary, the effects indicate that applying oils, particularly castor oil, increases the burn time of incense sticks.

11 ANOVA

Based on the above model an ANOVA was performed to determine if the treatments have a significant effect on the burn time of Agrabathi.

Table 4: Analysis of Variance

	DF	SS	MSS	F	P(>F)
Block	2	13198564	6599282.1	19.732	0.0000001
Treatment	2	7760310	3880155.2	11.602	0.0000371
Interaction	4	2017034	504258.5	1.508	0.2076683
Error	81	27089795	334441.9	NA	NA

The F-value for blocks is 19.73 with a very low p-value ($p = 1.00 \times 10^{-7}$), indicating that the variability between blocks is highly significant and thus it was reasonable to block for the brands of Agrabathi used. The significant p-value for blocks suggests that differences between blocks are substantial, meaning that the block effect is crucial in explaining the variability in burn time.

The F-value for treatments is 11.6 with a low p-value ($p = 3.71 \times 10^{-54}$), suggesting that the differences between treatments are also significant. This is to say that the application of one of the treatments has an effect on the burn time of Agrabathi. At this stage it is unclear which treatment (or even the control) is responsible for this conclusion. The specific cause of this effect is analysed more deeply by the contrasts considered in the following section. The significant p-value for treatments indicates that the treatments have a meaningful impact on burn time, suggesting that different treatments result in different burn times.

The F-value for the interaction term is 1.5 which a p-value of 0.207. This suggests that the a priori assumption that there is interaction between treatment and block effects is incorrect. The large p-value further suggests that the model used is incorrect and the interaction between blocking and treatment factors can be left out of the model in order to provide more power to the ANOVA if needed.

The residuals provide insight into the unexplained variation after accounting for block and treatment effects. Although this variation is present, it's relatively small compared to the explained variance from blocks and treatments.

Since the p-value<0.05 for the treatment effect, there is sufficient evidence to reject the null hypothesis and conclude that different oils (treatments) affect the burn time of incense sticks.

12 Contrasts

This study examines 2 planned contrasts, viz., if there is a difference in the burn time of Agrabathi when no oil is applied versus when oil is applied and if there is difference in the burn time of Agrabathi when coconut oil is applied as opposed to castor oil.

To account for these comparisons this study sets a maximum allowable experiment-wise type I error rate of 5. The comparisons are then corrected via the Bonferroni method to ensure this limit is upheld.

Formally we consider the following contrasts:

$$L_1 = \mu_{Coconut} - \mu_{Castor}$$
$$L_2 = \mu_{No\ Oil} - \frac{1}{2}(\mu_{Coconut} + \mu_{Castor})$$

Note that L_1 and L_2 are orthogonal contrasts and thus partition the sum square treatment. The table below summarises the analysis of the contrasts.

This reveals an interesting nuance to the data. In the previous section we concluded that there is indeed an effect induced by the treatments. Contrast L_2 compares the effect of no oil to the effect of applying oil and this

Table 5: Analysis of Contrasts

	DF	SS	MSS	F	P(>F)
Treatment	2	7760310.4	3880155.2	11.331	0.0000
L1	1	94562.5	94562.5	0.276	0.6006
L2	1	7665747.9	7665747.9	22.386	0.0000
Error	2	13198564.2	6599282.1	19.272	0.0000
Total	85	29106828.9	342433.3	NA	NA

shows that there is a statistically significant difference between them with $p = 8.79 \times 10^{-6}$. Conversely contrast L_1 shows little effect ($p = 0.60$) which is to say that there is little difference between the types of oil applied.

Bonferroni corrected confidence intervals for these contrasts are now constructed to ensure that the conclusions drawn above are valid and not simply type I errors. This study will permit a tolerance of $\alpha = 5\%$ for type I errors. This is to say that the conclusions are drawn with 95% confidence. The choice of Bonferroni's correction was made as only a priori contrasts are considered and there is small number of them. Had the study performed a post hoc analysis and made all pairwise-comparisons more sophisticated methods such as Tukey's or Sheffe's would have been selected.

Table 6: Bonferroni corrected confidence intervals

	Lower Bound	Upper Bound	Point Estimate
Contrast L1	-189.905	110.507	-39.699
Contrast L2	-586.178	-239.292	-412.735

Based on these intervals the conclusions drawn by the initial analysis of the p-values is correct as the confidence for L_1 contains zero thus there is no significant difference between the oils. Similarly the confidence interval for L_2 does not contain zero and thus there is a difference between the application of oil versus no oil.

13 Model Validation

This section will test the assumptions made in Section 8, viz., normality, homoscedasticity (of data and residuals), and the presence of the interaction effect.

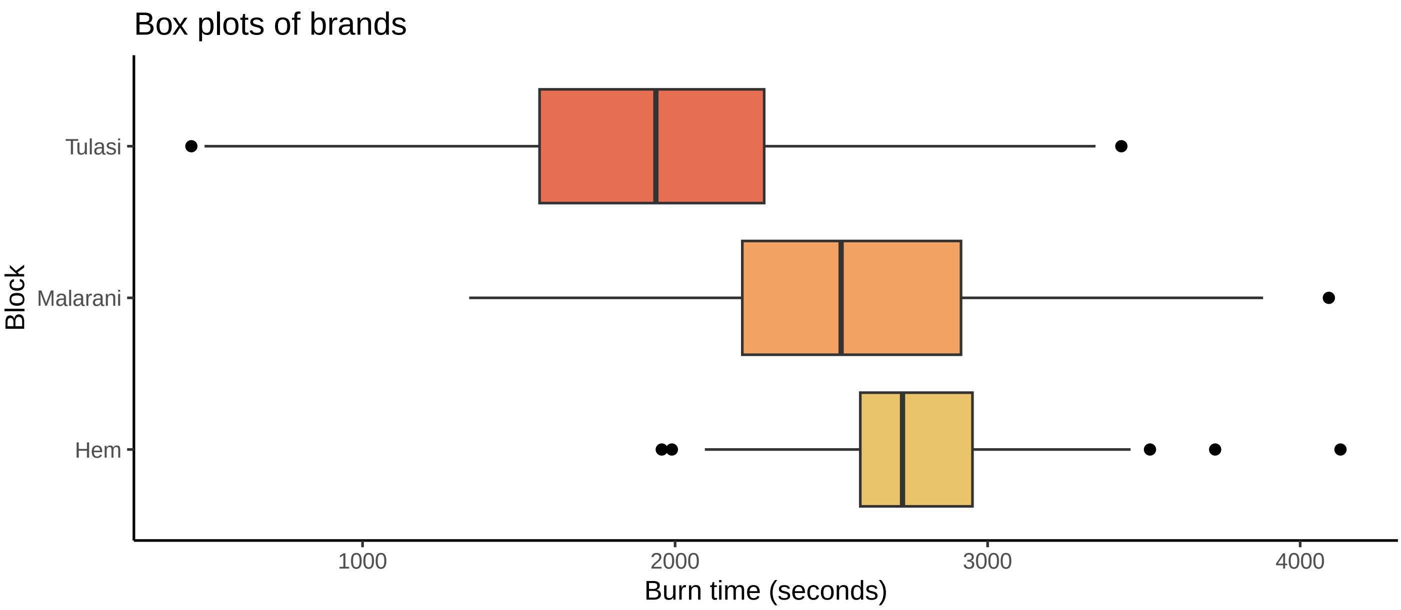

Figure 1: Box plot of brands versus burn time

In Figure 1, there is an equal proportion of the inner quartile range both above and below the mean and the tails of the boxplots are symmetrical, these properties are evidence that the data follows a normal distribution.

In a randomized block design, it's important to check if the data within each block follows a normal distribution. This helps ensure that the residuals of the ANOVA model are likely to be normally distributed, which is a key assumption for the validity of the F-tests.

Non-normality may indicate potential issues like outliers or skewed data, which could violate ANOVA's assumptions and lead to inaccurate conclusions. It is visually clear from Figure 1 that the data is normal. The whiskers on the box plots are approximately equal across the blocks, yet slightly shorter for 'Hem' than 'Malarani' or 'Tulasi'. Due to an approximate average length of whiskers across the blocks, one can conclude equal variances. A Levene test is nevertheless performed to ensure accuracy since there is some disparity within the 'Hem' block of this exploratory analysis.

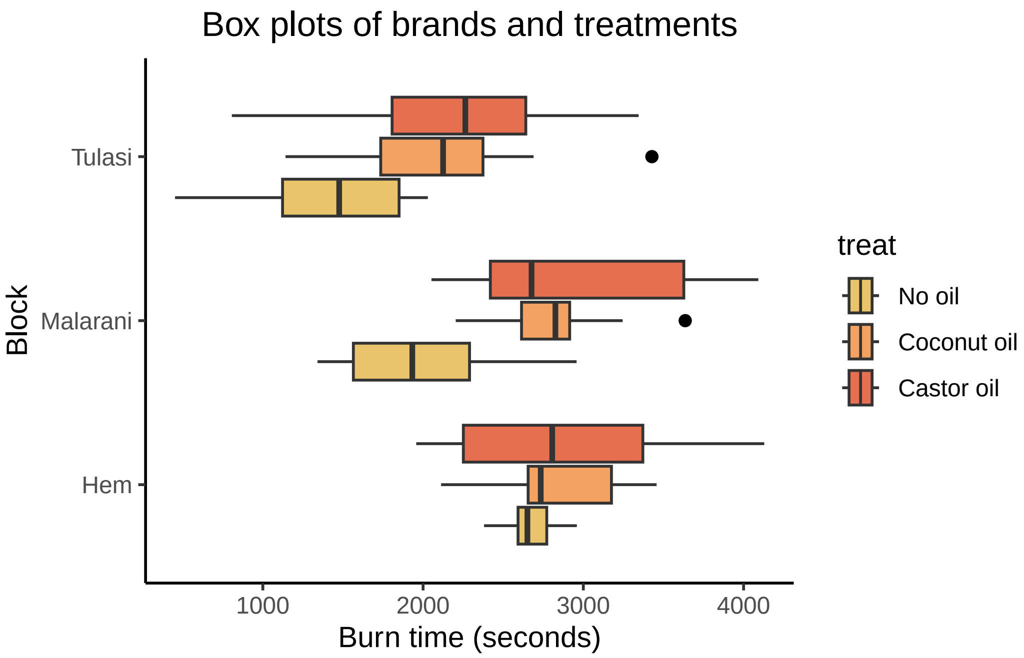

Figure 2: Box plot of brands and treatments versus burn time

Figure 2 delves into the treatments within the blocks. Within the Hem block:

1. Treatment 1: The burn times are clustered, a small interquartile range and short, symmetric tails.
2. Treatment 2: The median is approximately the same as treatment 1 (control) yet a larger variability is evident. The lower tail seems to be slightly longer than the upper tail indicating a possible left skew (even though very small difference in tail length).
3. Treatment 3: High variability, clear positive skew due to a longer upper tail. The median is marginally above the median for Treatment 1 & 2. The large spread suggests increased burn time under this treatment.

Within the Malarani block:

1. Treatment 1: Significantly lower median compared to other treatments in block 2. There is a positive skew due to a longer upper tail. There is a much lower median present compared to the same treatment in block 1.
2. Treatment 2: There is an outlier present in this data, suggesting that we have an observation which is quite far from the rest of the data. The median is the highest in this block even though the data is grouped quite closely (smallest IQR of block 2). The entire distribution is shifted upward relative to treatment 1 in this block yet treatment 2's lower quartile overlaps with the upper quartile of treatment 1.
3. Treatment 3: High Variability and is potentially right skewed.

Within the Tulasi block:

1. Treatment 1: Lowest median in this block and overall blocks, there is a clear left-skew due to asymmetric tail length.
2. Treatment 2: Symmetric tails and median which appears to be in the center of the IQR, larger variability compared to Treatment 2 in the other 2 blocks (longer tails).

3. Treatment 3: Highest median in this block with a symmetrical box plot (central median and approximately equal tail length).

The overall impression of this more in-depth analysis of the box plots does seem to indicate some inconsistencies which do not represent an accurate normal distribution with homoscedasticity. This is due to asymmetric tail lengths, non-central medians and tail lengths of treatments which are not consistent throughout blocks. While there are these indications of a stray from a normal distribution, an inspection of the Shapiro Wilk normality test will test if this is a result of significant non-normality or simple randomness within the data.

The null hypothesis for this test would be that the data is normally distributed while the alternate hypothesis would be that the data follows a different distribution. Since our p-value is quite large $p = 0.5643 > 0.5$, therefore there is insufficient evidence to reject the null hypothesis, thus the distribution of the reponse variable is normal.

The variability among blocks and treatments will also be further explored by means of a Levene test. This is to establish homoscedasticity of the treatment groups. The null hypothesis of this test is that the population variances between the groups is equal. The alternate hypothesis is that there is a difference in the variance of the population underlykng each treatment group. The Levene test fails to reject the null hypothesis ($p = 0.44$). This is to say that the variance between groups is equal and the assumption of homoscedasticity is met.

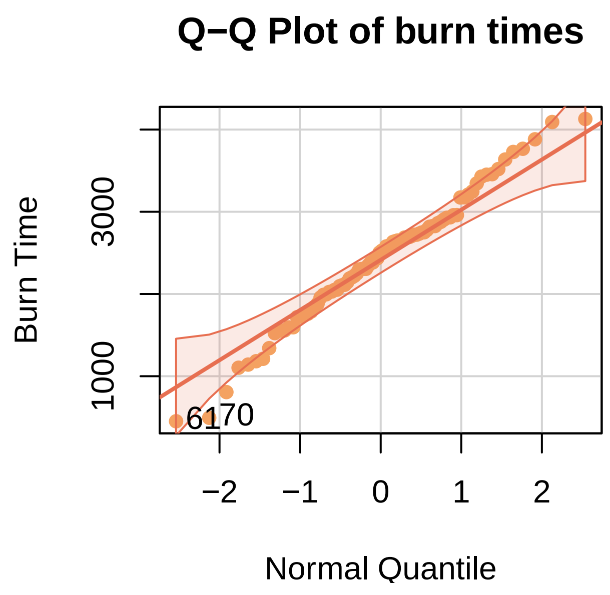

Figure 3: Q-Q plot of burn times

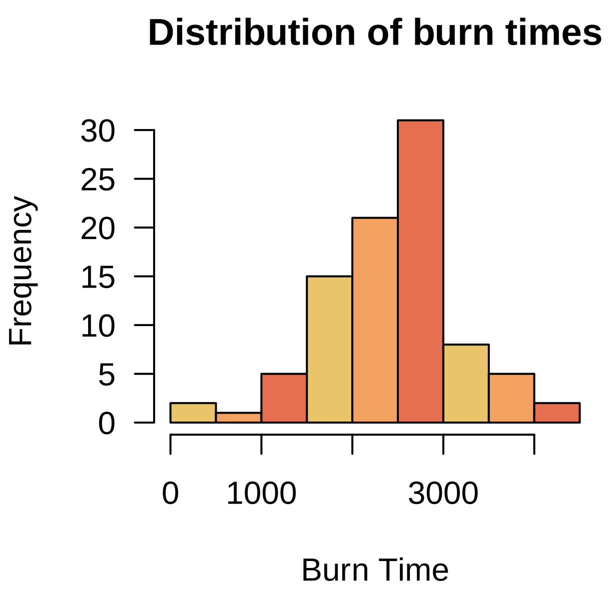

Figure 4: Histogram of burn times

The Q-Q plot, Figure 3, suggests that the central portion of the burn time data follows a normal distribution reasonably well, as the points around the middle of the plot lie close to the straight line. However, there are notable deviations at both ends, with the lower tail showing lighter-than-expected behavior (fewer extreme small values) and the upper tail indicating heavier-than-expected values (more extreme large values). These deviations from the line, particularly at the tails, suggest that the data does not fully adhere to the assumption of normality. The plot shows a confidence band. Points falling within this band suggest acceptable deviations from normality. However, several points in the tails fall outside the band, strengthening the evidence of non-normality in the extremes.

The histogram, Figure 4, of burn time data appears to have a slight right skew. Most of the burn time values are concentrated between 1500 and 3500, with a peak frequency around 2500. There are a few observations with higher burn times, reaching up to 4000, which contribute to the right tail. This skewness aligns with what is seen in the Q-Q plot, where the points in the upper quantiles deviate above the line, indicating heavier tails on the right side. While the overall distribution of burn times does not seem to be drastically skewed, the deviations in the tail could suggest a slight departure from normality, as indicated by both the histogram and the Q-Q plot.

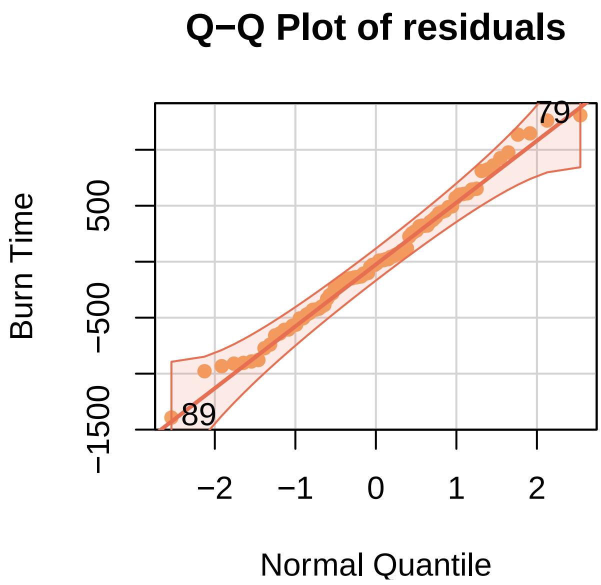

Figure 5: Q-Q plot of residuals of burn times

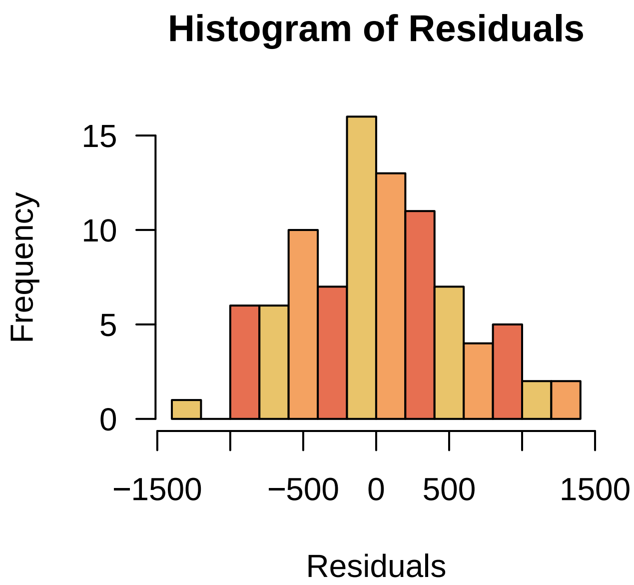

Figure 6: Histogram of residuals of burn times

A Levene test was conducted on the residuals within groups to establish the homoscedacity of the residuals. The test concludes that the residuals are drawn from populations of equal variance with an observed p-value of 0.4419.

The histogram of the residuals show a bell-shaped curve which is a well-known characteristic of a normal distribution. There is asymmetry present, indicating there are more positive residuals than negative ones (prediction is lower than our observed value) which signals that our assumption of normality might be violated. Yet the Shapiro Test confirms normality with an observed p-value of 0.578.

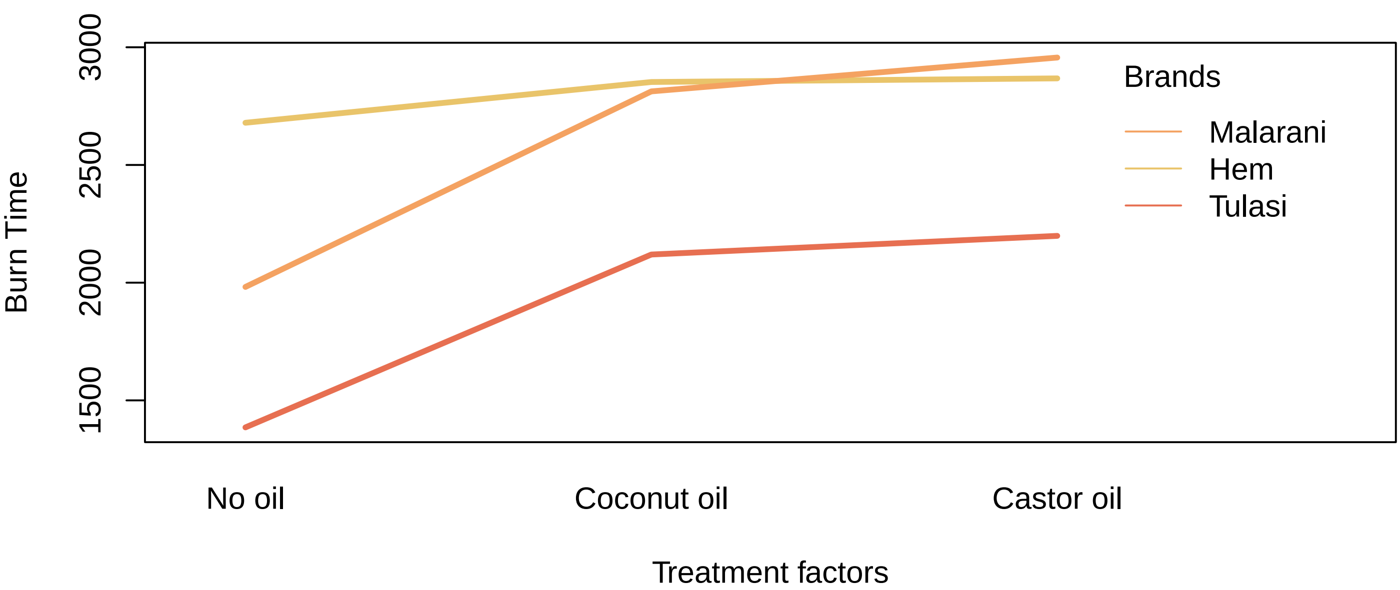

Figure 7: Interaction plot of treatment factors and blocking factors

The interaction plot, Figure 7, reveals that the relationship between the treatment (No oil, Coconut oil, Castor oil) and burn time varies depending on the brand of incense stick (Malarani, Hem, Tulasi), indicating a potential interaction effect. For example, Malarani shows a large difference in burn times between “No oil” and “Castor oil,” while Hem shows a smaller difference, suggesting the oils have less impact on burn time for Hem sticks. Tulasi exhibits moderate differences but generally has lower burn times across all treatments. The non-parallel lines in the plot confirm that the effect of the treatments differs across brands, which is indicative of an interaction. However, despite the visual evidence of interaction, the large p-value (insert p value) from the ANOVA suggests that this interaction is not statistically significant, implying that the observed differences in treatment effects across brands could be due to random variation rather than a meaningful interaction.

As such not all of the assumptions made in the model used by this study are justified. The data exhibits homoscedasticity in both the response variable and the residuals. The data is drawn from an underlying normal distribution as required. However the assumption of an interactive model is not met. This is to say that there is no significant presence of an interaction effect and thus the model should have been additive.

14 Conclusion

The purpose of this experiment was to determine whether different oils affected the burn time of Agrabathi sticks. The study posed questions of interest as to whether outcomes differed based on the type of oil used and whether it was impactful to use oil at all. The contrasts were formulated around these questions and their results proved that the type of oil used did not matter yet using oil compared to no oil had a significant impact.

The null hypothesis was that oil had no impact on the burn time of Agrabathi, essentially saying that the old wives tale was false and using oil compared to no oil produced the same burn time (the type of oil was irrelevant). Based on the ANOVA there is sufficient evidence to reject the null hypothesis. This is based on a significance level of $\alpha = 0.05$. This shows that the observed data is extremely unlikely if the null hypothesis was true.

While considerable efforts were made to ensure the validity of this experiment — by randomizing the assignment of treatments, blocking for different Agrabathi brands to account for external variances, and conducting statistical tests to confirm that the data met the assumptions for the ANOVA (such as equal variances, normality, and independence between experimental units)— there are still areas where improvements could be made. One notable strength of the experiment was the successful execution of a pilot study. The pilot provided valuable insights into the experimental process, helping to refine the procedure before the full experiment was conducted.

While the study attempted to minimise external influences, conducting the experiment outdoors introduced some variability due to fluctuations in temperature, wind, and sunlight. A more controlled environment—such as a large, empty room, would have reduced these variances and provided more reliable measurements of burn time.

Additionally, the financial feasibility of using oils like castor and coconut oil was not fully explored in this study. Future research could incorporate an analysis of the cost-benefit ratio to help users decide whether the investment in these oils is justified based on their impact on burn time. By adding this practical layer, the results could be more useful for families looking to balance tradition and cost-effectiveness.

Lastly, increasing the number of blocks and treatments would enhance the robustness and generalizability of the findings. Exploring a wider variety of brands and oils could lead to more comprehensive conclusions, providing greater insight into the factors that influence burn time.

Overall the experiment provided some valuable insights into traditional practices and offers practical advice for modern users. By understanding how different oils impact burn time, one can make more informed decisions about their use in cultural and spiritual practices.

15 Appendix

The following data was collected during the pilot study.

Table 7: Pilot Study Data

Block	Treatment	Time	Block	Treatment	Time	Block	Treatment	Time
Hem	No oil	2361.207	Malarani	No oil	2257.879	Tulasi	No oil	1246.721
Hem	No oil	2367.005	Malarani	No oil	2229.006	Tulasi	No oil	1244.780
Hem	Coconut oil	3030.465	Malarani	Coconut oil	2802.813	Tulasi	Coconut oil	2147.311
Hem	Coconut oil	2953.798	Malarani	Coconut oil	2759.087	Tulasi	Coconut oil	2161.314
Hem	Castor oil	2862.300	Malarani	Castor oil	2827.090	Tulasi	Castor oil	2277.839
Hem	Castor oil	3102.306	Malarani	Castor oil	2843.083	Tulasi	Castor oil	2360.059

Based on this data, Levene's test was conducted to establish homoscedasticity which it verified at the 5% level with an observed p-value of 0.75. Additionally the Shapiro-Wilk test was run to establish the normality of the data which it rejected with a p-value of 0.02. This is to say that the data deviates from a normal distribution. This raises some concerns as to the validity of the data used in the study however when data was simulated it was coerced into a normal distribution to ensure the validity of the results in this study.

From this pilot study, it was confirmed that the data was homoscedastic, which is a critical assumption for ANOVA. However, it also revealed that the data was not normally distributed. This deviation from normality, while not invalidating the experiment, could have impacted the precision of the results. In future studies, one might consider using transformations or non-parametric tests to account for non-normal data, or one could explore alternative experimental designs to better capture the true distribution of the data.

The original randomisation used is given below:

Table 8: Randomisation within blocks

Block	EU1	EU2	EU3	Block	EU1	EU2	EU3	Block	EU1	EU2	EU3
Tulasi	B	C	A	Malarani	C	A	B	Tulasi	C	A	B
Tulasi	A	B	C	Hem	A	C	B	Malarani	B	C	A
Malarani	A	C	B	Malarani	A	C	B	Malarani	C	A	B
Tulasi	A	C	B	Hem	A	C	B	Hem	B	A	C
Malarani	C	A	B	Hem	C	B	A	Tulasi	B	A	C
Tulasi	A	C	B	Hem	C	B	A	Hem	A	B	C
Malarani	A	C	B	Tulasi	C	A	B	Malarani	C	A	B
Malarani	C	A	B	Malarani	C	A	B	Tulasi	C	A	B
Tulasi	C	B	A	Malarani	A	B	C	Hem	B	C	A
Tulasi	B	C	A	Malarani	A	C	B	Tulasi	C	B	A
Tulasi	A	C	B	Hem	C	B	A	Malarani	C	B	A
Malarani	C	B	A	Tulasi	C	B	A	Tulasi	A	B	C
Hem	A	C	B	Hem	C	B	A	Tulasi	C	B	A
Malarani	B	C	A	Hem	C	B	A	Tulasi	C	A	B
Malarani	A	B	C	Hem	C	B	A	Tulasi	C	A	B
Tulasi	A	B	C	Malarani	A	B	C	Hem	C	A	B
Tulasi	B	C	A	Tulasi	B	A	C	Malarani	C	A	B
Hem	C	B	A	Tulasi	C	B	A	Malarani	C	B	A
Malarani	B	C	A	Malarani	C	A	B	Hem	A	C	B
Hem	A	C	B	Malarani	C	B	A	Hem	A	C	B
Hem	A	C	B	Hem	A	B	C	Malarani	B	A	C
Hem	C	A	B	Hem	C	B	A	Malarani	A	C	B
Tulasi	C	B	A	Tulasi	C	A	B	Tulasi	B	A	C
Hem	B	A	C	Malarani	C	B	A	Tulasi	A	B	C

Hem	B	A	C	Tulasi	C	B	A	Hem	C	A	B
Malarani	A	C	B	Hem	C	B	A	Hem	C	B	A
Hem	C	B	A	Malarani	C	A	B	Tulasi	B	A	C
Malarani	C	B	A	Hem	A	B	C	Malarani	A	C	B
Tulasi	C	B	A	Malarani	C	A	B	Tulasi	C	B	A
Hem	C	A	B	Hem	A	C	B	Tulasi	B	C	A

The full data (after sorting) for the experiment is given below:

Table 9: Simulated Data

Block	Treatment	Time	Block	Treatment	Time	Block	Treatment	Time
Hem	No oil	2650.52	Malarani	No oil	2249.20	Tulasi	No oil	452.18
Hem	No oil	2778.79	Malarani	No oil	2957.83	Tulasi	No oil	1103.27
Hem	No oil	2959.54	Malarani	No oil	1595.54	Tulasi	No oil	1211.85
Hem	No oil	2633.50	Malarani	No oil	2427.34	Tulasi	No oil	1880.19
Hem	No oil	2904.92	Malarani	No oil	1524.07	Tulasi	No oil	2030.02
Hem	No oil	2578.90	Malarani	No oil	2303.44	Tulasi	No oil	1996.75
Hem	No oil	2651.63	Malarani	No oil	1554.89	Tulasi	No oil	1760.28
Hem	No oil	2502.97	Malarani	No oil	2024.11	Tulasi	No oil	1741.08
Hem	No oil	2380.37	Malarani	No oil	1341.17	Tulasi	No oil	1182.21
Hem	No oil	2751.19	Malarani	No oil	1841.51	Tulasi	No oil	494.38
Hem	Coconut oil	3451.04	Malarani	Coconut oil	2826.85	Tulasi	Coconut oil	1141.39
Hem	Coconut oil	2642.67	Malarani	Coconut oil	3245.29	Tulasi	Coconut oil	2689.80
Hem	Coconut oil	2347.56	Malarani	Coconut oil	2824.54	Tulasi	Coconut oil	1787.24
Hem	Coconut oil	3457.35	Malarani	Coconut oil	2583.40	Tulasi	Coconut oil	1718.23
Hem	Coconut oil	2694.25	Malarani	Coconut oil	2203.70	Tulasi	Coconut oil	2188.99
Hem	Coconut oil	2721.57	Malarani	Coconut oil	2305.80	Tulasi	Coconut oil	1557.45
Hem	Coconut oil	3173.94	Malarani	Coconut oil	2860.95	Tulasi	Coconut oil	2435.41
Hem	Coconut oil	3176.18	Malarani	Coconut oil	2932.78	Tulasi	Coconut oil	2143.03
Hem	Coconut oil	2112.36	Malarani	Coconut oil	3635.85	Tulasi	Coconut oil	3427.84
Hem	Coconut oil	2747.01	Malarani	Coconut oil	2706.58	Tulasi	Coconut oil	2106.68
Hem	Castor oil	2927.33	Malarani	Castor oil	2526.17	Tulasi	Castor oil	1592.96
Hem	Castor oil	3727.90	Malarani	Castor oil	4091.81	Tulasi	Castor oil	2306.24
Hem	Castor oil	2733.71	Malarani	Castor oil	2817.52	Tulasi	Castor oil	1725.67
Hem	Castor oil	2719.98	Malarani	Castor oil	2297.82	Tulasi	Castor oil	2598.43
Hem	Castor oil	4128.95	Malarani	Castor oil	3208.61	Tulasi	Castor oil	2221.36
Hem	Castor oil	2878.00	Malarani	Castor oil	2052.49	Tulasi	Castor oil	2686.83
Hem	Castor oil	1957.29	Malarani	Castor oil	3881.38	Tulasi	Castor oil	3345.11
Hem	Castor oil	1989.65	Malarani	Castor oil	2384.12	Tulasi	Castor oil	2049.30
Hem	Castor oil	3519.47	Malarani	Castor oil	2536.16	Tulasi	Castor oil	806.64
Hem	Castor oil	2095.15	Malarani	Castor oil	3766.51	Tulasi	Castor oil	2655.15