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.

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1 Introduction

This assignment explores the influence of different oil treatments on the burn time of incense sticks through the application of a randomized block design (RBD). This study is structured around 3 distinct treatment types (..) randomly applied across 18 experimental units, with the incense brand serving as a blocking factor. 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, we aim to minimize the impact of confounding variables, allowing us to attribute any variations in burn time more confidently to the treatments themselves rather than to the intrinsic characteristics of the incense sticks.

2 Motivation

There is an old wives tale which hails from the ancient Indian subcontinent and has been told for generations; applying oil to an incense stick will cause it to burn faster. This quick burn time ensured that the smoke created a sacred atmosphere, a well scented home and most importantly, carried your family's prayers to the almighty deities above. While there can be no doubt about the role of incense sticks (or Agrabathi) in the cultural and spiritual settings of an Indian home, doubt remained about the effectiveness of dipping these sticks into the rich, often fragranced, oils. This study seeks to unravel the truth behind this age-old belief, offering modern families the wisdom to discern whether investing in extra oils for incense sticks truly enhances both their connection to the divine and the speed in which the fragrance emanates throughout their homes. By providing this knowledge, we aim to empower families to make informed decisions and potentially save them from unnecessary expenses if these treatments are found not to significantly extend the burn time of incense sticks.

3 Objectives

Our objective is to determine which treatment has an effect on burn time looking at three treatment: a control, castor oil, and coconut oil. We will examine whether these commonly used oils differ from each other (comparison of castor and coconut oil) and whether there is a difference with the oils from the control (comparing each oil individually to the control). By blocking for the different brands of incense sticks, we can more confidently deduce the differences between treatments, as the blocks contain homogeneous units. Once the incense sticks are lit and the smoke clears, the last burning stick will reveal whether oils truly influence burn time. By repeating this experiment three times, we ensure that our findings are as robust as the scent that lingers in the air.

Formally this study will test the following hypothesis:

> 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:

> L_1: Effect of sandalwood 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 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.

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 **Link to the relevant section**.

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 below:

Table 1: Sample Randomisation

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

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

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. **Check the skew dir**These insights suggest a need for more data to test for significant effects.

7 Data collection and Assumptions

The full experiment was run with 30 replications per block. This took place using the same experimental and randomisation procedure as outlined above. The orginal data is given in the Appendix. Normality tests were then conducted to justify the assumptions which will be made (discussed in the next section) in the model. **Add in all of Dhiya's analysis here and typeset**

8 Model

This study will employ the following model for the data:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$$

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 corner point constraint such that $\alpha_1 = 0$. Additionally we assume an additive model and thus exclude the possibility of interaction between block and treatment effects. **add what each term represents, check the model used in ANOVA**

This model will make the following assumptions:

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

These assumptions are justified in the previous section as **add in this stuff based on Dhiya's analysis**

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.

10 ANOVA

11 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.

Table 3: 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

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 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 4: 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

12 Conclusion

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13 Appendix

The original randomisation used is given below:

Table 5: Randomisation within blocks

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

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

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

Table 6: Randomisation within blocks

block	treat	time
Hem	No oil	2650.5227
Hem	No oil	2778.7920
Hem	No oil	2959.5394

Hem	No oil	2633.4956
Hem	No oil	2904.9172
Hem	No oil	2578.9041
Hem	No oil	2651.6279
Hem	No oil	2502.9739
Hem	No oil	2380.3736
Hem	No oil	2751.1898
Hem	Coconut oil	3451.0439
Hem	Coconut oil	2642.6727
Hem	Coconut oil	2347.5647
Hem	Coconut oil	3457.3515
Hem	Coconut oil	2694.2535
Hem	Coconut oil	2721.5697
Hem	Coconut oil	3173.9402
Hem	Coconut oil	3176.1767
Hem	Coconut oil	2112.3550
Hem	Coconut oil	2747.0112
Hem	Castor oil	2927.3282
Hem	Castor oil	3727.8999
Hem	Castor oil	2733.7080
Hem	Castor oil	2719.9791
Hem	Castor oil	4128.9509
Hem	Castor oil	2877.9955
Hem	Castor oil	1957.2929
Hem	Castor oil	1989.6532
Hem	Castor oil	3519.4677
Hem	Castor oil	2095.1505
Malarani	No oil	2249.2034
Malarani	No oil	2957.8254
Malarani	No oil	1595.5402
Malarani	No oil	2427.3412
Malarani	No oil	1524.0672
Malarani	No oil	2303.4432
Malarani	No oil	1554.8915
Malarani	No oil	2024.1093
Malarani	No oil	1341.1688
Malarani	No oil	1841.5132
Malarani	Coconut oil	2826.8532
Malarani	Coconut oil	3245.2903
Malarani	Coconut oil	2824.5364
Malarani	Coconut oil	2583.3981
Malarani	Coconut oil	2203.6966
Malarani	Coconut oil	2305.7980
Malarani	Coconut oil	2860.9482
Malarani	Coconut oil	2932.7839
Malarani	Coconut oil	3635.8458
Malarani	Coconut oil	2706.5840
Malarani	Castor oil	2526.1670
Malarani	Castor oil	4091.8076
Malarani	Castor oil	2817.5176
Malarani	Castor oil	2297.8197
Malarani	Castor oil	3208.6125

Malarani	Castor oil	2052.4874
Malarani	Castor oil	3881.3805
Malarani	Castor oil	2384.1233
Malarani	Castor oil	2536.1593
Malarani	Castor oil	3766.5081
Tulasi	No oil	452.1814
Tulasi	No oil	1103.2669
Tulasi	No oil	1211.8502
Tulasi	No oil	1880.1949
Tulasi	No oil	2030.0183
Tulasi	No oil	1996.7522
Tulasi	No oil	1760.2772
Tulasi	No oil	1741.0815
Tulasi	No oil	1182.2138
Tulasi	No oil	494.3818
Tulasi	Coconut oil	1141.3884
Tulasi	Coconut oil	2689.8000
Tulasi	Coconut oil	1787.2440
Tulasi	Coconut oil	1718.2321
Tulasi	Coconut oil	2188.9874
Tulasi	Coconut oil	1557.4480
Tulasi	Coconut oil	2435.4088
Tulasi	Coconut oil	2143.0334
Tulasi	Coconut oil	3427.8434
Tulasi	Coconut oil	2106.6795
Tulasi	Castor oil	1592.9635
Tulasi	Castor oil	2306.2427
Tulasi	Castor oil	1725.6686
Tulasi	Castor oil	2598.4327
Tulasi	Castor oil	2221.3615
Tulasi	Castor oil	2686.8291
Tulasi	Castor oil	3345.1062
Tulasi	Castor oil	2049.2998
Tulasi	Castor oil	806.6389
Tulasi	Castor oil	2655.1505